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OUTLOOK ON AGRICULTURE

Volume II Number 5

Winter 1959

The design in linocut on the cover is a composite of drawings from two medieval manuscripts. In the centre is a figure from the works of Matthew Paris, who entered St. Alban's as a monk in 1217. Surrounding this, depicting farming activities throughout the year, are drawings based on MS. from the Benedictine Abbey of Sweifalten, circa 1162.

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THE WORLD FOOD PROBLEM

In times of stress, ever since the days of Malthus, the problem of feeding the world's expanding population has been repeatedly raised. Books have been written on the subject, and numerous surveys have shown that, taking the situation as a whole, more food is required than is being produced and that supplies per head will diminish unless steps to remedy matters are taken in time. The basic facts have never been in dispute, but as each crisis passed and conditions regularly returned to normal the theory seemed to lose its validity, and its protagonists have been derisively called "prophets of doom." The world, it was popularly assumed, could provide a good ration for all into the distant future.

Experiences during and after the second world war have done much to change this attitude. Starvation or its threat forced many nations towards a higher degree of self-sufficiency, and those who have gained independence have been striving to improve their standards of living. In consequence the peoples of nearly all lands are today producing and consuming slightly more food per head than they did in pre-war years. That, however, is no reason for complacency. Populations are rising alarmingly, and such authorities as Prof. A. Toynbee and Dr. L. H. Matthews have recently been urging birth control as well as increased food production as the only ways of avoiding famine.

Mr. H. J. Page in his article in this number takes doubling of the world's food production in the next 40 years as a reasonable minimum, and he shows that this can be achieved if cultivators in Asiatic countries where land is plentiful and yields are low can be provided with fertilizers and taught to use them in a proper way. Other techniques for raising the output of crops and stock can help and, with some increase in the cultivated area and economic aid from outside, tide over until the end of this century.

Far graver issues, however, seem bound to follow—and that within the lifetime of our grandchildren. If the world's population continues to expand at its present rate (47 million were added in 1958) it will double every 50 years, and so too must the food supply. Thus, to meet food requirements only 150 years ahead the 1958 supply must be multiplied eight times, and in the course of that period the time available for producing each successive increment will become less and less, falling to a mere 12 years or so by A.D. 2100. It is difficult to see how production levels of this order are to be reached in time.

It took Britain some five centuries to treble wheat yields per acre, and in the past 100 years, during which all the innovations of modern science came to be applied to the crop, the rise has been only 60%. The less advanced lands may improve on this rate for a time, but eventually and everywhere yields per acre must slow down as biological or physical limiting factors come more and more into play. Whatever discoveries may be made, yields cannot continue to double indefinitely, either of crops or livestock.

There is of course still plenty of scope for expansion of the cultivable area; but every year an increasingly large amount of land is lost to agriculture, and it is evident that reclamation must proceed more rapidly than it is doing today. More research must be devoted to all aspects of the subject. Engineering difficulties may yet be overcome by the use of atomic power. Crops may be bred that will grow in cold and arid regions. Deserts may be made fruitful by the use of underground water, rain-making, and the conversion of sea to fresh water—all processes now in their infancy. Acres may also be gained as industrial crops are replaced by synthetic products.

While such influences are gradually taking effect our food supplies will no doubt also be augmented by a wider use of such techniques as algal photosynthesis, the extraction of proteins from vegetable matter, and the microbial synthesis of both proteins and fats. Fresh discoveries will assuredly be made and applied to farming in all its branches, and before productivity of the land reaches its maximum we may well be exploiting the vast resources of the sea and subsisting in part on food of synthetic origin.

Such is the nature of the food problem. Many governments are slowly introducing the social, political and agricultural reforms that its solution demands, but from what has been said it is clear that bold and imaginative measures will need to be taken promptly. Concern is not with remote contingencies, to be averted by hoped-for miracles of scientific achievement before there is "standing room only" on the earth's surface, but with the timely planning of populations and with basic agricultural practices.

TRENDS IN FERTILIZER CONSUMPTION IN RELATION TO WORLD FOOD SUPPLY

H. J. Page

(*Formerly Principal, Imperial College of Tropical Agriculture, Trinidad*)

From this study of trends in fertilizer consumption the author concludes that "if fertilizers can be supplied in adequate amounts to cultivators in the low-consumption countries, especially in the East, and are properly used, the production of food-crops can be profitably increased more than sufficiently to feed the world's population for many generations to come." But great concomitant developments must take place if this is to be achieved.

A study of trends in the consumption of fertilizers in various countries, on which to base a forecast of world fertilizer consumption in the future, is far from being a dry-as-dust academic exercise of interest only to the economist. It is a matter of vital importance to all mankind.

Barring some global disaster, the world's population at its present rate of growth will reach well over 4000 millions by the end of this century—an increase of over 60% above the number today. To feed these extra 1500–2000 million people, even at the prevailing world average ration per head, the total production of foodstuffs must also expand by over 60%. Having regard to the fact that well over half the world's people get barely enough food for subsistence, and very many live in constant hunger on (or over) the verge of starvation, no target less than the doubling of the world's food production in the next forty years can be accepted as a reasonable minimum.

These considerations are now common knowledge, not merely to demographers, nutrition experts and agricultural scientists, but to the general public, and much has been written and published [e.g. 2, 4]. It is also recognized that fertilizers must be included in programmes for raising agricultural productivity to the level needed for such an enormous increase in food supplies. It is, however, not generally realized that they must play an all-important part, not merely as one of various alternative means to this end, but that they are indeed a *key* factor in practically all schemes for increased food supplies the world over.

Among the various possible means of increasing the production of food crops, besides a greater use of fertilizers, are (1) the breeding of intrinsically higher-yielding varieties of crop plants (hybrid maize is an outstanding example); (2) the prevention or reduction of losses caused by pests and diseases and weeds by the breeding of resistant varieties and by the use of plant protection treatments (e.g. fungicides, insecticides, selective weed-killers); and (3) improved cultivation methods and better husbandry generally. On arid or semi-arid land or in times of drought, lack of moisture in the soil is the overriding limiting factor; in such conditions improved water supply by irrigation and drainage is the first essential, without which neither fertilizers nor any of the other potential means of raising agricultural productivity can be effective. But even on land that is adequately watered by natural means or by irrigation the full benefits of the other measures cannot be realized unless manures or fertilizers (of the right kinds and used in the right way) are also applied.

No crop growing in adequately moist soil can give the yield of which it is potentially capable without enough plant food in the soil; the higher the yield of which it is capable, the more plant food it needs, and the faster does it exhaust the soil unless enough food is supplied to meet this need and to maintain the necessary high level of soil fertility. It is largely wasted effort to change over to a new high-yielding or diseases-resistant crop variety, or to apply crop protection or better cultivation methods, if the fertility of the soil is so low that the crop is starved. This holds even when arid land is newly brought into cultivation by irrigation, for although such land may contain dormant stores of plant food which become mobilized by the supply of irrigation water and which may then suffice to produce high crop yields at first, these natural reserves will be depleted by a few successive crops and yields will fall unless soil fertility is replenished by manures and fertilizers.

Although much of the plant food required may be supplied by bulky farm-produced organic manures—and their use along with fertilizers is a necessary feature of the best farming practice—the quantities available are usually far from enough to fill the needs of high-yielding crops. It can be assumed that such organic manures are already being fully utilized in helping to maintain the existing levels of crop production, and that fertilizers are therefore a key factor in producing the extra crops needed to feed the future population, no matter what other means of increasing crop production are also used. It is for this reason that a study of the trends in the world's fertilizer consumption is a matter of vital importance.

The part of the world's land surface that is classified as agricultural land (arable, tree crops, permanent meadows and pastures) totals nearly 4000 million hectares [1], and the remainder, apart from land under forests, amounts to another 6000 million hectares, of which over 500 million are classified as unused but potentially productive. Much of the area classified as waste land in the remaining 5500 million hectares, as well as a part of the further nearly 4000 million hectares of forests, could no doubt ultimately be brought into cultivation for food production if the need were compelling.

But the bringing into cultivation of arid and waste land involves great capital expenditure on irrigation, drainage, roads, and the like. Although many costly projects have been and are being carried out, especially in countries where the need for more food production is most urgent, the more immediately effective and less expensive way of materially increasing crop production is to raise the level of yields on land already in cultivation but which is now not yielding nearly as much as it could. It is this aspect of fertilizer use, and its bearing on fertilizer consumption in the future, that it is the main purpose of this article to consider. Growth of the world's population renders further increases in fertilizer use inevitable, and a study of the data available can help to indicate how, when and where such increases will occur.

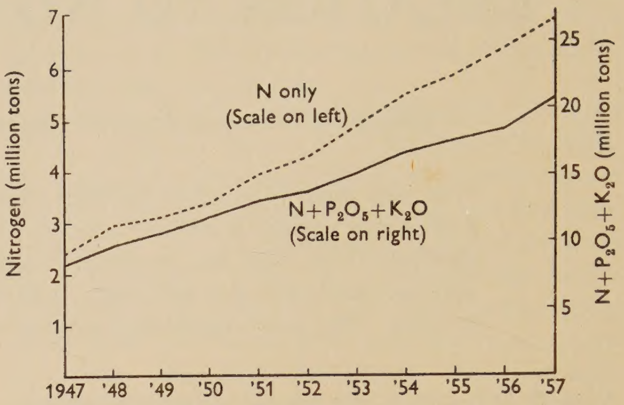

FIG. 1. World consumption of fertilizers, 1947–57, in millions of tons.

The total world consumption of fertilizers,* which in 1947 had just regained its pre-war level, increased steadily during the following decade, as shown graphically in Figure 1. For every 100 tons of the three nutrients $N+P_2O_5+K_2O$ used in 1947 nearly 250 tons were used in 1957, while for every 100 tons of nitrogen in 1947 the amount consumed in 1957 was nearly 300 tons. These increases over ten years correspond to cumulative average *annual* increases of over 9%

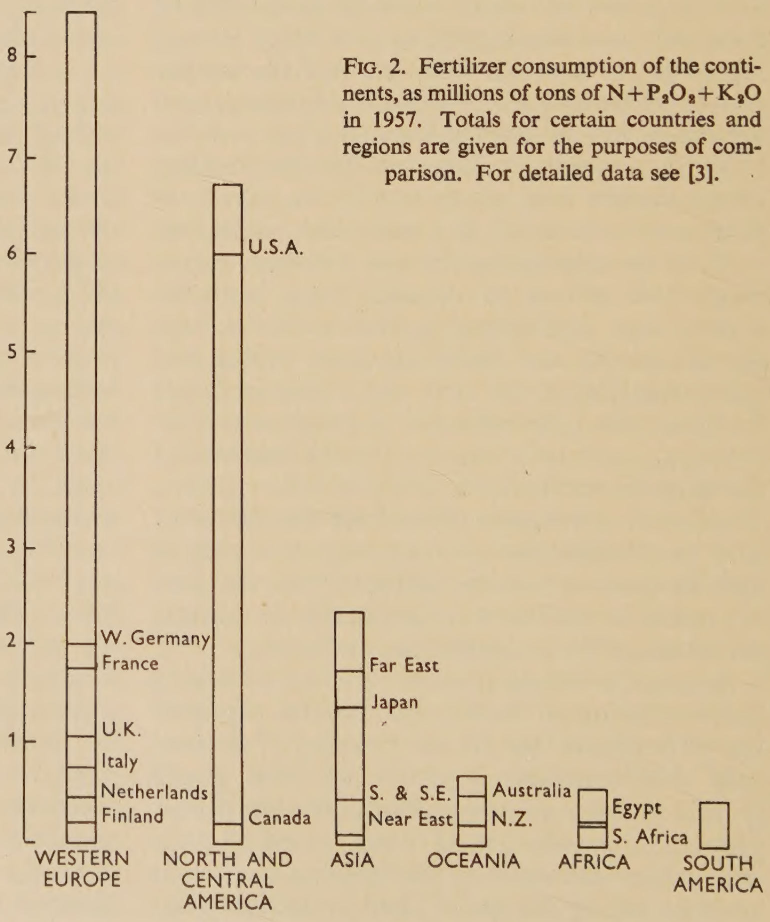

FIG. 2. Fertilizer consumption of the continents, as millions of tons of $N+P_2O_2+K_2O$ in 1957. Totals for certain countries and regions are given for the purposes of comparison. For detailed data see [3].

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* Except for the population and land-area data given in the earlier part of this article, all the data presented are exclusive of the U.S.S.R., the Chinese Peoples' Republic and North Korea. Population data are for 1956 [1]. Fertilizer data are expressed in metric tons of nitrogen (N), phosphoric acid (P_2O_5) and potash (K_2O) contained in commercial fertilizers.

for $N+P_2O_5+K_2O$ and over 11% for nitrogen. The actual amounts consumed in 1957 were:

	Million tons
Nitrogen (N)	6·89
Phosphoric acid (P_2O_5)	8·35
Potash (K_2O)	6·73
Total	21·97

While these figures demonstrate the great increases which have occurred globally, and that the trend seems to be for the rate of increase to become even faster, especially for nitrogen, it is only when they are broken down to enable comparisons to be made between various countries and regions that their true significance becomes clearer.

TABLE I

RELATIVE SHARES OF THE CONTINENTS AND OF HIGH-CONSUMPTION AND LOW-CONSUMPTION COUNTRIES OR REGIONS IN WORLD CONSUMPTION OF FERTILIZERS ($N+P_2O_5+K_2O$) IN 1957

Continent	Total consumption (mill. tons)	% of world consumption	Area of agric. land (mill. ha.)	Rate of application (kg./ha.)
Western Europe	8·4	38	149	56
North and Central America*	6·7	30	614	11
South America	0·4	2	363	1
Africa	0·6	3	798	1
Asia†	2·3	10	860	3
Oceania	0·7	3	402	2
Industrialized countries or regions				
Western Europe	8·4	38	149	56
U.S.A.	6·0	27	444	14
Canada	0·2	1	62	3
Union of S. Africa	0·2	1	97	2
Japan and Formosa	1·5	7	7	203
Australia and New Zealand	0·7	3	399	2
Total	17·0	77	1158 (36%)	15
Rest of world‡	5·0	23	2029 (64%)	2½
World total‡	22·0	100	3187	6 (weighted mean)

* Including Caribbean islands.

† Excluding Chinese Peoples' Republic and North Korea.

‡ Excluding U.S.S.R., Chinese Peoples' Republic and North Korea.

TABLE II

INCREASES IN FERTILIZER CONSUMPTION, 1947–57 (millions of tons of $N+P_2O_5+K_2O$)

Region	1946–7	1956–7	Increase
Western Europe	3·6	8·4	4·8
U.S.A.	3·1	6·0	2·9
Japan	0·5*	1·4	0·9
Central America†	0·03	0·15	0·12
South America	0·14	0·40	0·26
Africa‡	0·05	0·19	0·14
Asia, Near East	0·02	0·11	0·09
Asia, S. and S.E.	0·11	0·44	0·33

* Data for 1947–8 (1946–7 not available).

† Including Caribbean.

‡ Excluding Egypt and Union of South Africa.

Until recent years the manufacture of fertilizers has been almost wholly confined to highly industrialized countries, and it is therefore not surprising that they also use far more fertilizer than the economically less developed countries. Out of the 22 million tons world consumption of fertilizer nutrients in 1957, nearly four-fifths (17 million) was consumed in the more highly industrialized countries listed in Table I, although the area of agricultural land in these countries is less than two-fifths of the world total. In other words, the highly industrialized countries use about 3½ times as much fertilizer as the rest of the world, at an average rate over six times as high per unit area of farmed land. This contrast is more clearly shown in Figure 2, which is based on the data in Table I. Moreover, whereas in Western Europe and Japan most of the agricultural land is more or less intensively farmed, in the U.S.A., Canada, South Africa, Australia and New Zealand this is true for only a relatively small part of the land; in these countries much of the fertilizer is used on the more intensively farmed areas and little on the rest, so that the *average* rate is low, concealing the fact that rates for the intensively farmed areas are comparable with the high averages for Western Europe and Japan. Western Europe and Japan between them account for 45% of the world's consumption, giving an average rate per cultivated acre 16 times that for the rest of the world.

At first it might be expected that the trend for further increase would be much less in the industrialized countries where consumption is already high than in the less developed countries where fertilizer use is low or even nil, and which therefore have so much greater scope for improvement. But a study of fertilizer consumption since 1947 shows that this is far from generally true. In Table II are shown the increases in the decade 1947–57 for Western Europe, U.S.A. and Japan on the one hand, and for Central America, South America, Africa and Asia (Near East and S. and S.E. Asia) on the other. Although percentage-wise the increases are of the same order in the two groups, the quantities used in the latter are so small that they would have to be multiplied many times to reach those in the former. The total consumption of South America is less than that of the Netherlands and less than two-fifths of that of the United Kingdom. The continent of Africa consumes less than Italy, two-thirds of it in South Africa and Egypt. In Asia (excluding U.S.S.R., Chinese Peoples' Republic and North Korea) the total consumption is little more than double that of the United Kingdom, and Japan accounts for over half of this. This contrast is strongly emphasized if the figures are expressed in relation to the areas of agricultural land concerned (Table III).

Moreover, if figures for the individual countries are compared we find that there are a few non-European countries in which the intensity of fertilizer use is of the same order as that in Western Europe. Table IV shows, in descending order of magnitude, all countries whose average rate of application in 1957 was over 10 kg. of $N+P_2O_5+K_2O$ per hectare of agricultural land,* i.e. "high-consumption countries."

TABLE III

AVERAGE RATES OF FERTILIZER APPLICATION ($N+P_2O_5+K_2O$) IN 1957 PER HECTARE OF AGRICULTURAL LAND

Country or region	Application (kg./ha.)	% of rate for Western Europe
Western Europe	56	100
U.S.A.	14	25
Japan	215	387
Central America	7·3	13
South America	1·1	2
Africa	0·8	1½
Asia, Near East	0·6	1
Asia, S. and S.E. . .	1·6	3

TABLE IV

AVERAGE RATES OF FERTILIZER APPLICATION ($N+P_2O_5+K_2O$) IN 1957 FOR HIGH-CONSUMPTION COUNTRIES, AS KILOGRAMS PER HECTARE OF AGRICULTURAL LAND.

Western Europe		Other countries	
Belgium	205	Japan	215
Netherlands . .	198	Formosa	146
Norway	141	Barbados	146
West Germany . .	137	Mauritius	115
Denmark	120	Israel	108
Luxembourg . .	100	Egypt	88
Finland	71	Reunion	68
Sweden	67	Ceylon	51
United Kingdom . .	53	S. Korea	51
France	52	Lebanon	43
Austria	41	Trinidad	28
Italy	35	Jamaica	20
Switzerland . .	34	Malaya	17
Portugal	28	Cyprus	17
Ireland	25	Chile	14
Spain	18	El Salvador . .	11
Weighted average . .	56	Weighted average . .	73
		Weighted average (excluding Japan)	38
World average: 6			

North America, Australia and New Zealand, all with low average rates of application and low population densities, have been left out of special consideration in the analysis which follows. With their various patterns of huge reserves of potentially productive farmland, high industrial development, plentiful resources of raw materials, or large exportable surpluses of agricultural produce, raw materials or manufactured goods, the question of increased fertilizer use for intensifying agricultural production is governed by considerations of national policy beyond the scope of this article. In Mexico, where big agricultural developments are in progress, fertilizer consumption has multiplied over fivefold since 1953; for Australia and New Zealand the rise over the same period has been about one-third; but in both the U.S.A. and

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* 1 kg./ha.=0·9 lb./acre approximately.

Canada consumption has scarcely increased at all, and in the U.S.A., as a result of over-production and the accumulation of huge stocks of surplus agricultural produce, the area of cultivated land has been restricted by law.

In Table V the two sets of figures in Table IV are shown again, flanked on the left by the percentage increases in fertilizer consumption over the four-year period 1953–7, and on the right by a "population factor" which expresses the pressure of the population on the farmed land (total population divided by area of agricultural land in hectares).

For the countries of both groups trends can be seen for the rate of consumption to increase where the intensity of use is relatively low, and for the higher values of that intensity to apply to countries with the higher pressure of population on their agricultural land. But these trends, although obvious and to be expected, are not clear cut, being confused by various other factors such as, for the Western European countries, the differing proportions of grassland (low fertilizer use) to tillage land (higher fertilizer use) and, especially, the effects of national policies in fostering self-sufficiency in food production or the importation of food.

TABLE V

INCREASES IN FERTILIZER CONSUMPTION ($N+P_2O_5+K_2O$), AND POPULATION FACTORS, IN RELATION TO AVERAGE RATES OF APPLICATION PER HECTARE OF AGRICULTURAL LAND FOR HIGH-CONSUMPTION COUNTRIES

Country	Consumpt. % incr. 1953–7	Rate in 1957 (kg./ha.)	Population factor*
EUROPE			
Belgium	16	205	5·1
Netherlands	6	198	4·8
Norway	19	141	3·4
Western Germany ..	25	137	3·7
Denmark	13	120	1·4
Luxembourg ..	0	100	2·2
Finland	32	71	1·5
Sweden	23	67	1·6
United Kingdom ..	19	53	2·6
France	59	52	1·3
Austria	117	41	1·7
Italy	29	35	2·3
Switzerland	22	34	2·3
Portugal	26	28	1·8
Ireland	47	25	0·6
Spain	45	18	1·0
NON-EUROPE			
Japan	60	215	14·1
Formosa	24	146	9·9
Barbados	50	146	6·9
Mauritius	50	115	4·6
Israel	225	108	3·0
Egypt	90	88	9·0
Reunion	4	68	3·0
Ceylon	133	51	6·0
South Korea	63†	51	10·9
Lebanon	100	43	5·4
Trinidad	64	28	4·2
Jamaica	38	20	3·8
Malaya	320	17	3·5
Cyprus	29	17	1·0
Chile	79	14	1·3
El Salvador	250‡	11	1·8

* Number of total population per hectare of agricultural land.
† 460 in 1955–7.
‡ 1954–7.

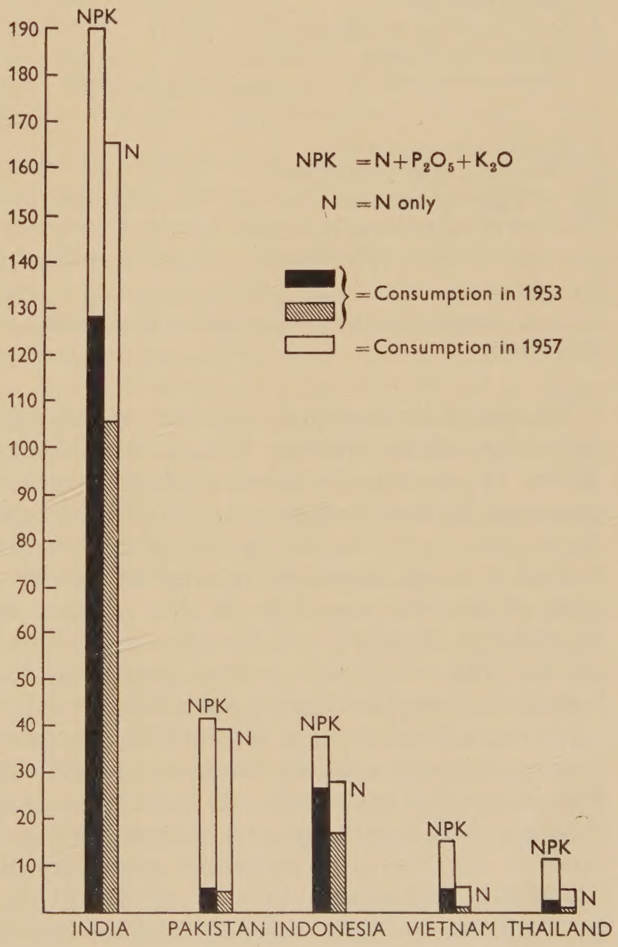

FIG. 3. Fertilizer consumption in certain countries in S. and S.E. Asia in 1953 and 1957, as thousands of tons of $N+P_2O_5+K_2O$ and of N.

TABLE VI

COMPARISON OF NON-EUROPEAN HIGH-CONSUMPTION COUNTRIES WITH THE REST OF REGIONS TO WHICH THEY BELONG

Region or country	Population, 1956 (mill.)	Area of agric. land, 1957		Consumption of $N+P_2O_5+K_2O$	
		% of regional total	Per head (ha.)	% of regional total	Rate of application (kg./ha.)
Central America (incl. Caribbean)					
Barbados, Jamaica, Trinidad, El Salvador	5	8	0·4	25	18
Rest of region	22	92	1	75	4·6
South America					
Chile	7	< 2	0·8	21	14
Rest of South America	120	>98	3	79	0·9
Africa					
Egypt, Mauritius, Reunion	24	< 1	0·1	40	89
Rest of Africa	195	>99	4	60	0·5
Asia—Near East					
Cyprus, Israel, Lebanon	4	< 1	0·4	76	61
Rest of Near East*	76	>99	2·5	24	0·1
Asia—South and South-east					
Ceylon and Malaya	17	< 2	0·2	26	31
Rest of S. and S.E.†	659	>98	0·4	74	1·3
Above regions as a whole					
Countries using > 10 kg./ha. ("high consumption")	57	1	0·3	33	36
Rest of regions using 10 kg./ha. or less ("low consumption")	1072	99	1·5	67	0·7

* Aden, Afghanistan, Iran, Iraq, Jordan, Saudi Arabia, Syria, Turkey.

† British Borneo, Burma, Cambodia, India, Indonesia, Laos, Nepal, Pakistan, Philippines, Thailand, Vietnam.

The parallelism between intensity of fertilizer use and population pressure is much more clearly shown by the non-European high-consumption countries, the only marked exceptions being South Korea (still in process of rehabilitation after the Korean war) and Egypt (which is better able than most of the other countries in this category to finance food imports partly from non-agricultural exports, and which also receives annual contributions to its soil fertility from the Nile floods).

However, fertilizer usage of these non-European high-consumption countries (excepting Japan) has little direct bearing on the world situation, for their populations and areas are almost negligibly small in relation to those of the continents of which they form part. In most of them, too, fertilizer use is largely on commercially owned plantations growing export crops (sugar, cotton, tea, rubber, bananas, etc.) and not in the peasant agriculture on which depend the food supplies of the less developed countries which make up so much of the world. The fairly wide range in the intensity of fertilizer use in the non-European high-consumption countries is partly a reflection of the relative proportions of their land given up to such plantations. Commercial plantation companies have both the means of financing fertilizer expenditure and the technical staff to ensure that fertilizers are used to the best advantage, thus affording examples of how, even in a non-industrialized country, by the rational use of fertilizers on a scale similar to that in W. Europe, the national economy can benefit and agricultural exports can help to finance food imports.

So far we have confined our attention mainly to trends in the high-consumption countries and we have seen that, in general, the greater the pressure of population on the farmed land the higher is the intensity of fertilizer use, and the greater the rate at which consumption is increasing. But although

TABLE VII

POPULATION, AGRICULTURAL LAND, AND FERTILIZER USE ($N+P_2O_5+K_2O$) IN S. AND S.E. ASIAN COUNTRIES IN DESCENDING ORDER OF PRESSURE OF POPULATION ON AGRICULTURAL LAND

Country	Population 1956 (mill.)	Agricultural land		Rate of fertilizer use, 1957 (kg./ha.)	% increase in consumption in 4 years (1953–7)	
		Total (mill. ha.)	Per head (ha.)		NPK	N
Vietnam	26·6	4·5	0·17	3·1	185	323
Ceylon	9·2	1·5	0·17	51·0	133	91
Indonesia..	84·0	17·7	0·21	2·0	47	48
Pakistan	83·6	24·4	0·29	1·7	651	530
Malaya	7·5	2·2	0·30	17·0	320	243
Philippines	22·3	7·6	0·34	3·0	*	*
Nepal	8·4	3·1	0·37	Nil	—	—
Thailand	20·7	7·8	0·38	1·3	225	222
India	387·0	169·5	0·43	1·1	49	57
Burma	19·9	8·6	0·43	0·1	129	400
Cambodia	4·4	2·0	0·45	Nil	—	—
Laos	1·5	2·0	1·4	Nil	—	—
British Borneo	1·1	3·6	2·9	0·3	†	†
Totals or means ..	672·6	254·5	0·38	1·7	98‡	91‡

* Not available. † Negligible in 1953. ‡ Excluding Philippines.

these countries account for nearly half of the world's consumption, they represent less than 7% of the world's agricultural land. Table VI gives a comparison of this small minority of non-European high-consumption countries with the rest of the respective regions to which they belong.

Up to a point the figures in Table VI speak for themselves. South America, Africa and Near East Asia are relatively sparsely populated (together they contain 82% of the agricultural land of the five regions concerned but only 38% of their total population), and in the "low-consumption countries" (i.e. those using 10 kg. or less of fertilizer plant food per hectare) the average areas of agricultural land per head range from 2½ to 4 ha. Central America (containing only 1·5% of the agricultural land of the five regions and 2·4% of their population) has, as an average for the low-consumption countries, one hectare (2½ acres) per head. But in S. and S.E. Asia (with 60% of the population of the five regions and 16% of their agricultural land) there is only 0·4 ha. (1 acre) per head.

It is therefore not difficult to understand why consumption is still so low in South America, Africa and Near East Asia. What little fertilizer is consumed is used for the most part on commercial plantations and the peasant farmers have, generally, enough land to produce their fairly adequate (though sub-optimal) food supplies by extensive farming without fertilizers and with primitive methods, giving low crop yields per acre. In consequence, until the pressure of population becomes much higher, large increases in fertilizer consumption are not to be expected; an early acceleration in the rate of use is likely only if there is a marked tendency for the level of diet and the general standard of living to rise, and then only, in arid and semi-arid areas, especially in Near East Asia, in conjunction with important irrigation schemes.

Central America is a borderline region. Although the average pressure of population is still moderate, in most of the smaller Caribbean islands the area per head is much below the average (less than 0·5 ha.), so that they depend largely on outside economic aid for their subsistence and must use far more fertilizer before they can become self-supporting. But their areas and populations are so small that any increase would represent very little on the world scale.

In S. and S.E. Asia the situation is very different. Here are a quarter of the world's population with only one-fifteenth of the agricultural land, and except for sparsely populated Laos and British Borneo no country has more than 0·45 ha. per head, and some less than 0·2; yet the application of fertilizer plant food averages only 1·7 kg./ha. Detailed data are given in Table VII. The percentage increases shown do not, of course, give any indication of the amounts involved; for example, India's 49% represents a rise from 128 to 191 thousand tons, while Pakistan's 651% refers to an increase from 5½ to 42 thousand tons. The amounts consumed in five of the countries in Table VII in 1953 and 1957 are shown graphically in Figure 3.

India's consumption in 1957 was nearly half the total for S. and S.E. Asia. India and Pakistan together consumed more than half (54%) of that total and over two-thirds of the nitrogen of the region, yet this was less than a quarter of the consumption in the United Kingdom, although their population was over nine times as great and their area of agricultural land ten times as great. Moreover, their population is increasing rapidly—in India alone by about 5 million a year. But, unlike the countries of Western Europe, which can afford to import much of their food, even India with its growing industrial development has not the resources to finance large imports of food or fertilizers. Small wonder, therefore, that the peoples of S. and S.E. Asia suffer from chronic undernourishment and are in constant need of economic aid from outside. Large increases in fertilizer consumption are one of the indispensable requirements for growing the extra crops to feed the ever-increasing population, even at the present sub-standard level of diet, let alone for growing enough food to raise that level. And since all countries have free access to unlimited supplies of the prime raw material for the manufacture of nitrogen fertilizers—the nitrogen of our atmosphere—it is not surprising that throughout S. and S.E. Asia the erection of nitrogen-fixing fertilizer factories takes high priority in their development plans. In India several new factories are being erected or are planned; in Pakistan three; and others in the Philippines, Burma, Malaya and Indonesia; while in the Far East two factories are under construction and another is planned in South Korea. New superphosphate factories are also projected in several countries.

An outstanding example of the importance given to the promotion of fertilizer use in national development plans in S. and S.E. Asia is afforded by the Indian second and third five-year plans, in which the targets for consumption of $N+P_2O_5+K_2O$ are 695,000 tons in 1961–2 and 1,750,000 tons in 1965–6, the latter figure being over nine times the consumption in 1957.

The attainment of such objectives demands not only the availability of the fertilizers, home-produced or imported, but the education of the peasant in their use. Such education can become effective only by letting the cultivators *see* the results of proper use of fertilizers on their own fields. A large scheme for the conduct of simple standard trials, each of only about half a dozen plots, was pioneered by Mukerjee in Bihar, and is now being employed throughout India, Pakistan and many other countries of S. and S.E. Asia, much of it with the assistance of F.A.O. (especially through its International Rice Commission), the U.S.A. (Point 4), the Colombo Plan, etc. This method affords a striking example of how demonstration and experimental work can be combined; a properly designed scheme of simple trials on cultivators' fields can also serve, in association with more elaborate "response curve" experiments (using incremental fertilizer dressings) at official experimental stations, to determine what are the best kinds of fertilizers and the most economic rates of application under varying conditions of crop, soil and climate. From a study of a large volume of data from such trials and experiments in India [7] the conclusion reached was "that, at present prices, 20 lb. nitrogen per acre as sulphate of ammonia to food grains will be definitely profitable on most soils, and that an equal dressing of P_2O_5 will be equally good if restricted to the more responsive soils. From the point of view of the national balance of payments, such manuring is relatively even more advantageous than it is to individual cultivators: a large-scale programme of fertilizer use, if necessary temporarily aided by imports of fertilizer, could go far towards removing India's food deficit."

So much for the relatively near future. In this short article space does not permit discussion of a number of important details such as the trend towards the use of more concentrated fertilizers, e.g. urea (46% N) and double superphosphate (40–50% P_2O_5), especially for use up-country where high freight costs may add greatly to the delivered price. There is growing evidence, too, of the need to supplement nitrogen with phosphate or potash fertilizers.

In conclusion, let us consider the more distant future. It was stated at the beginning of this article that doubling of the world's food production in the next 40 years was the minimum reasonable target.

In 1953 Speyer [4], in a closely reasoned and thought-provoking article, concluded tentatively that if all the extra food required by the end of this century to feed the postulated extra 2000 million people in the world had to be produced through the use of fertilizers, the world consumption of fertilizer nitrogen would have to increase from the present figure of about 7 million tons a year to 57 million tons, an eightfold increase.

But it need not be assumed that all the extra food required can be produced *only* through the use of nitrogen fertilizers, adequately supplemented by phosphates and potash. Only a part of the crops on which the present world population of over 2500 million mainly depend for their food consists of the extra yields resulting from the use of fertilizers containing 7 million tons of nitrogen. Yates has estimated that 1 ton of nitrogen applied to food crops can produce on the average enough extra food to nourish 40 persons for a year. Seven million tons of nitrogen would, on this basis, produce enough for 280 million people. Hence only about one-tenth of the world's food supplies today is the direct result of fertilizer use. The other nine-tenths are derived directly (or indirectly through animal products) from the nitrogen and other plant foods that crops get from the natural reserves in the soil, from farmyard manure, composts, etc., from biological fixation of atmospheric nitrogen by bacteria in the root nodules of legumes and in the soil, and from sea food. However, such a large proportion of the extra food required to feed another 2000 million people could not be derived from these non-fertilizer nitrogen sources. Let us assume that one half of it *could* be so derived, especially by growing more legumes. The fertilizer nitrogen needed to grow the other half would then amount to 25 (instead of 50) million tons in addition to the 7 million tons now consumed, i.e. a total annual nitrogen consumption of 32 million tons at the end of this century. This increase in 40 years would correspond to a cumulative annual increase of much less than the 10% which is about the rate at which world fertilizer consumption has so far been increasing.

It may therefore be concluded that, if trends in fertilizer consumption and production continue unchanged, fertilizer use could more than suffice to meet the world's food-production requirements during the next 40 years. And if the assumption underlying the above calculations (that only one half of the extra food crops need be derived from fertilizer nitrogen) is an under-estimate, so that the annual rate of increase in fertilizer production and consumption would need to be higher, perhaps even enough to produce *all* the extra food crops required, this would still be well within the current trend. There is, moreover, an indication of a tendency for the present rate of increase to rise.

Even if the world requirements of nitrogen, phosphate and potash fertilizers should all have to expand by the year 2000 to the same level as that postulated by Speyer for nitrogen, i.e. an eightfold rise, making about 170 million tons of $N+P_2O_5+K_2O$, this would correspond to an average world rate of about 45 kg./ha. of agricultural land, disregarding any possible extension in that area, which is still little more than one-fifth of the rate at which fertilizers are now used in Japan and some countries of Western Europe.

This is, of course, a gross oversimplification of the problem. It takes no account of the tremendous concomitant developments which would be required in irrigation, drainage and land reclamation schemes, the financial and transportation problems involved, and the like—the how, when and where—but it does at least suggest that the necessary increase in fertilizer use is inherently *possible*, however great may be the difficulties in translating the possible into the practicable.

A recent study by Walsh and Kilroy [6] affords strong support for this conclusion. In that study, from an analysis of the results of "response curves" derived from fertilizer field experiments in various O.E.E.C. member countries, estimates have been made of the rates of application of fertilizers which would result if all growers in those countries used enough to raise their crop yields up to the level beyond which further increases in yield would be worth less than the cost of the extra fertilizer needed to produce them. This level is termed the economic optimum fertilizer dressing, and its calculation involves the following factors: expected increase in production from each increment of fertilizer added; cost of fertilizer; price received for the crop; additional harvesting and marketing costs; residual effects. "The economic optimum fertilizer use for a country is the amount consumed if all farmers applied the most profitable quantities of fertilizers to the different crops grown."

Table VIII, derived from Walsh and Kilroy's data, shows the percentage of the 1957 consumption in nine West European countries and the corresponding increases in the rates of application

TABLE VIII

ESTIMATED ECONOMIC OPTIMUM FERTILIZER CONSUMPTION ($N+P_2O_5+K_2O$) AND RATE OF APPLICATION PER HECTARE OF AGRICULTURAL LAND, FOR VARIOUS WEST EUROPEAN COUNTRIES

(Calculated from estimates by Walsh and Kilroy [6])

Country	Optimum consumption as % of 1957 consumption	Rate of application (kg./ha.)	
		1957	Optimum
Austria	202	41	83
Belgium	122	205	250
Denmark	134	120	161
France	356	52	185
Western Germany ..	129	137	177
Ireland	452	25	113
Netherlands	93	198	184
Sweden	159	67	107
United Kingdom ..	165	53	88
Weighted mean ..	202	74	148

that would result from the estimated economic optimum fertilizer use. These estimates indicate that, even in the high-consumption countries of the West, the average potential economic fertilizer consumption is double the consumption in 1957. All available evidence indicates that, given adequate water and good husbandry, fertilizers of the right kinds and used correctly can be just as effective in other parts of the world, temperate or tropical, as they are in the West—and perhaps even more so.

There are therefore good grounds for concluding that, if fertilizers can be supplied in adequate amounts to cultivators in the low-consumption countries, especially in the East, and are properly used, the production of food crops can be profitably increased more than sufficiently to feed the world population for many generations to come, well beyond the end of the present century. It must be remembered, too, that the above economic optimum rates of fertilizer use are not the *maximum* rates capable of giving the highest crop yields, but only the rates which would give the most profitable yields at current fertilizer costs and crop prices. If the need for further increased food production eventually becomes imperative, crop prices will rise; and if the cost of fertilizers to the grower can also be reduced, fertilizers can be used efficiently and economically at rates even higher than the present highest estimates of optimum consumption.

Fertilizers are indeed a key factor in the problem of feeding an increasing world population, and it can safely be said that, whatever other factors might be responsible for a threat of world famine, if given a proper chance fertilizers can prevent it.

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IRRIGATION OF GRASSLAND

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Grassland in the drier parts of England frequently suffers from drought in the summer months, but it is rarely irrigated and there has been little experimental evidence to show either when to irrigate or how much water to apply. Technical data on both points and on the effects of irrigation and nitrogen treatments on the yield and composition of leys are provided by the trials described here, though the practical aspects are not considered.

In many parts of the world crops can only be grown if the land is irrigated. While this is not true of Britain, there are areas, as in south-east England, where plant growth is limited by lack of water. The effect is particularly noticed on pastures.

From the time of its establishment in 1927, Jealott's Hill Research Station (mean rainfall 25·7 in.) has been concerned with obtaining the maximum production from grassland. This involved attempts not only to increase the overall yield but to maintain as constant a rate of growth as possible during the summer months and thus overcome the mid-season decline that normally follows the spring flush. It was soon apparent that the maximum response to fertilizers could not be obtained if the water supply was inadequate.

In the early 1930s Greenhill [2] set out to find what rainfall would maintain uniform growth under Jealott's Hill conditions. In a replicated plot trial he supplemented the natural rainfall by watering one day each week, provided it had not reached a predetermined level in the previous week (0·69 or 0·84 in.), and in a year in which the spring and summer rainfall was above average he increased the yield by about 20% for the lower "rainfall" and 36% for the higher. A new set of experiments was initiated by A. H. Lewis in 1938 (unpublished work). He used the moisture content of the soil as the criterion of how much water to apply. In a replicated field experiment he restored the upper 4 in. once per week to an arbitrary level (mean values 14, 16 or 19 g. water/100 g. oven-dry soil). Marked increases in the yield of herbage were obtained, the greatest corresponding to the highest level of moisture. Both in this experiment and that of Greenhill, rates of nitrogen were factorially combined with the watering treatments: in each the highest yields were obtained with the maximum nitrogen and water usage. There was no interaction, but the ratio of clover to grass increased with irrigation. It was clear from these experiments that, even in years of average rainfall, large increases in yield were possible; but the methods used involved much labour.

Work was recommenced in 1949 with the hope of finding a technique that would involve the minimum of labour for maximum output. The aims were to find (*a*) when to irrigate and (*b*) how much water to apply.

IRRIGATION REQUIREMENTS

The approach to this problem at Jealott's Hill has been influenced by the work of Schofield [6] and Veihmeyer and Hendrickson [9]. It is well known that plant growth ceases long before all the soil water is used because of the increasing force (*p*F)* plants must apply to move water from the soil as it becomes drier. The water content at which growth ceases is generally known as the wilting percentage, and there has been a tendency to regard this as a constant for a given soil and independent of the plant species. There seems little justification for this, as Slatyer [7] has recently pointed out. The maximum force that has to be applied before growth will stop varies and with mesophytes is in the range 10–20 atm., so the water content of soil subjected to a tension of 15 atm. is generally taken as a working figure for the wilting percentage. A change of a few atmospheres on either side has a relatively small effect on the moisture content. Thus for mesophytes the wilting point approaches a constant for a soil.

It is obvious that irrigation will be necessary as the soil moisture content approaches the wilting percentage. But our object in irrigating grassland is to obtain the maximum yield, so the question is raised: is there a critical *p*F smaller than that at the wilting percentage ($pF = 4·18$) which, if exceeded, will cause a marked slow-down in the growth of pasture plants? An answer to this would give a good guide on when to irrigate, but none has been found in the literature.

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* In this paper the *p*F of a soil is taken as being equal to the log of the height in cm. of the water column equal to the suction necessary to remove water from or absorb it into a soil.

At Jealott's Hill we tried to get some information on this point by allowing soils under grass-clover swards to dry out to predetermined levels (i.e. a range of *p*F values) and then irrigating and measuring the effect of the treatments by the yields of herbage. The quantities of water required for irrigation had to be ascertained.

For practical purposes the water content of a soil carrying a *growing crop* fluctuates between field capacity (about *p*F 1·69–2·47) and the wilting percentage. For normal growth it should never be above field capacity for more than a day or two. If the depth of effective roots is known, together with the figures for field capacity and wilting percentage, the maximum amount of water available for a given crop can be found.

Our investigation on when to irrigate was made by comparing the effects on herbage yields of no irrigation with irrigation to field capacity when one-third, two-thirds, and nearly all the available water in the soil had been used, i.e. low, moderate and high *p*F values respectively were allowed to develop. Since this information applies only to the site of the experiments, we measured the approximate *p*F range in each water regime to obtain a universal value.

EXPERIMENTAL PROCEDURE

Two experiments with the above water regimes were carried out, one in 1951 and the other in 1953. Both were on established leys and on similar soils, with the upper 9 in. a loam with some stones (flints and cherts) passing into a sandy clay to clay. The underlying rock was London Clay, but this was never less than 3 ft. from the surface. The sites were tile drained at 21 in., providing reasonable drainage.

The techniques used to determine root depth, water content at field capacity, wilting percentage and apparent density of soil are described in the paper [4], of which this is a condensed version. Mean figures of the water content for each site are also listed, and it will suffice to mention here only that the weight of available water per acre foot was 175 tons (=1·7 in.) on the first site and 196 tons (=2·0 in.) on the second (effective root depth 1 ft.).

The plots measured 1/200 acre and were arranged in four randomized blocks. They were subdivided for 5 irrigation and 3 nitrogen treatments, these being repeated four times. Adequate levels of phosphorus and potash were maintained by applying to all plots the equivalent of 6 cwt. superphosphate and 3 cwt. muriate of potash per acre at the beginning of the season.

The swards were cut at the grazing stage, leaving about 1–2 in. of herbage. Irrigation was done very gently by hand, using a hose without a nozzle held close to the ground and water from a storage tank.

RESULTS

In 1949 and 1950 studies were made of soil moisture loss on irrigated and unirrigated plots in a grass-clover ley in its third and fourth years, nitrogen being applied in the form of sulphate of ammonia. By the spring of 1951 when the ley was in its fifth year there were three different swards corresponding to the three rates of nitrogen:

(i) No N: 30–40% clover, 30–40% perennial ryegrass and 30% cocksfoot.
(ii) Low rate of N: 5–10% clover, 50–55% perennial ryegrass and 40% cocksfoot.
(iii) High rate of N: no clover, 40% perennial ryegrass, 60% cocksfoot.

In Table I are the results of the treatments on the production of dry matter on the first site. There was no interaction between them. The year 1951 with 35·7 in. rainfall was the wettest on record at Jealott's Hill; but June and July were comparatively dry, and most of the increase occurred between 4th June and 6th August (rainfall 3·01 in.). April to September rainfall was 15·11 in.

TABLE I

EFFECTS OF TREATMENTS ON HERBAGE YIELD, WITH N AS SULPHATE OF AMMONIA, 1951

(Dry matter in cwt./acre)

Deficit before irrigation	Rates of N (lb./acre)			Mean yield
	0	46	92	
Unirrigated ..	62·4	65·4	74·4	67·4
1·7 in.	73·0	71·1	81·4	75·2
1·2 in.	80·1	78·9	86·0	81·7
1·2 in. (Met. data)*	80·5	76·9	86·9	81·4
0·6 in.	81·8	77·5	83·8	81·0
Mean yield ..	75·6	74·0	82·5	
Sig. diff. for N rates: 2·3; for watering methods: 3·2				

* Meteorological data obtained at Jealott's Hill were applied to a formula derived from the work of Penman [1] as described elsewhere [4].

The experiment was repeated in 1953 on the second site. The ley was in its third year and consisted of white clover 20% and perennial ryegrass 80% before fertilizers were applied. Five dressings of 'Nitro-Chalk' (15·5% N as NH_4NO_3) at 2½ and 5 cwt./acre were applied early in April and after the first, second, third and fourth cuts. All the plots were not cut simultaneously as in the first experiment, because it was thought this tended to penalize the results obtained with the highest rate of nitrogen; the grass on these plots was often ready for cutting many days before that on the plots receiving less or no nitrogen. All the plots of any one nitrogen treatment were cut at the same time, irrespective of the irrigation treatment. The weather in the summer was "average," with a rainfall from April to September (inclusive) of 13·26 in. against the 11·93 in. mean. June had the lowest rainfall, 1·40 in. (mean 1·58 in.).

The results are in Table II, and again there were no interactions between the nitrogen and irrigation treatments.

DISCUSSION

In both years there were clear responses to irrigation, but the water needs seemed to be related to the nitrogen treatment. The biggest dry matter response to irrigation was where no nitrogen was applied and when the soil water supply was kept at low tensions, which in turn necessitated the largest amount of irrigation (9 in.). With the lower rate of nitrogen there was no disadvantage in allowing greater tensions to develop, and at the higher even greater tensions which in turn corresponded to the smallest water consumption (3·5 in). From Figure 1 (which applied to the second experiment) it is seen that a *p*F greater than 3·34 should not have been allowed to develop for maximum production when no nitrogen was used, but with nitrogen at the lower rate a *p*F of 3·80, and at the higher rate one approaching 4·0, could be permitted. These values for the upper limit of *p*F for maximum production depend upon the nitrogen rate and seem linked with the botanical composition of the sward. When no nitrogen was applied, the more frequently the plots were irrigated (i.e. the lower the average *p*F) the greater was the proportion of clover, maximum clover content corresponding to maximum yield. A similar observation was made by A. H. Lewis in 1938 at Jealott's Hill, and also by

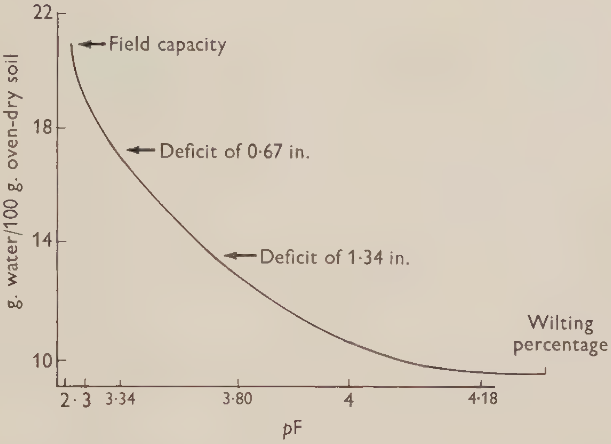


FIG. 1. Relationship between soil moisture content and *p*F, 1953.

TABLE II

EFFECTS OF TREATMENTS ON HERBAGE YIELD, WITH N AS 'NITRO-CHALK,' 1953

(Dry matter in cwt./acre)

Deficit before irrigation	Rates of N (lb./acre)			Mean yield
	0	43·5	87	
Unirrigated . .	67·8	88·9	112·1	89·6
2·0 in.	77·5	96·9	121·2	89·5
1·34 in.	82·9	103·9	123·4	103·4
1·34 in. (Met. data)	81·2	104·8	119·9	102·0
0·67 in.	86·4	104·7	123·8	105·0
Mean yield . .	79·2	99·8	120·1	
Sig. diff. for N rates: 2·9; for watering methods: 8·0				

TABLE III

EFFECTS OF TREATMENT ON BOTANICAL COMPOSITION OF SWARD, WITH N AS 'NITRO-CHALK,' 1953

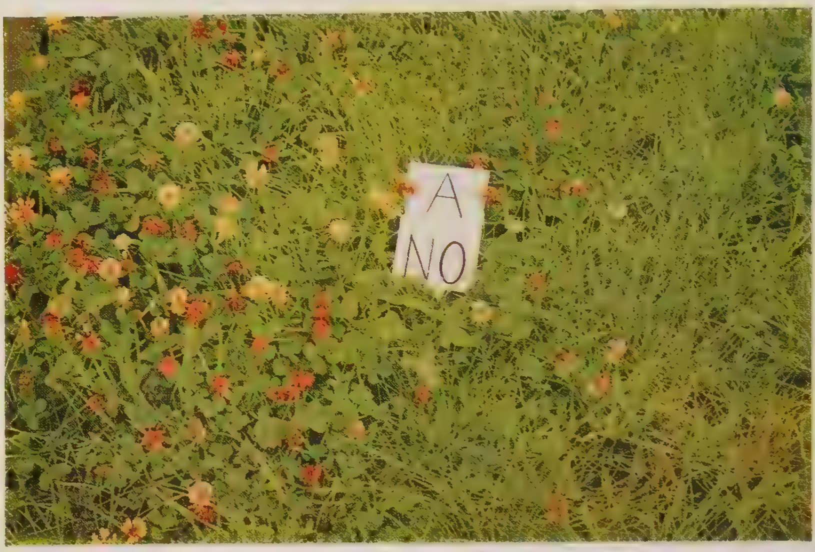
(Percentage clover at cut 4)

Deficit before irrigation	Rates of N (lb./acre)		
	0	43	86
Unirrigated	52	8	4
2·0 in.	60	14	3
1·34 in.	65	21	8
1·34 in. (Met. data) . .	63	29	11
0·56 in.	71	28	10
S.E. (single plot) . .	±5	±4	±2
Sig. diff. Probability: 0·05 . .	8	6	4

Robinson and Sprague [5] in the U.S.A. With the higher nitrogen rate the sward was predominantly grass, and a near-maximum yield was obtained even when high *p*F values were allowed to develop. Thus white clover grew most vigorously at low tensions and tended to compete strongly with the grasses for the available room. Grasses seemed to be able to grow vigorously over a wide *p*F range, provided there was plenty of nitrogen (Table II). That white clover could compete more vigorously with grasses as the availability of the water increased is illustrated by the fact that, for both nitrogen treatments, the clover content rose as the frequency of irrigation increased.

The difference in behaviour between the grass and clover under these irrigation regimes cannot be explained by the depth of their root systems. The high nitrogen rate on the grass tended to reduce root development.

The effect of water and nitrogen on the sward compositions in the second experiment is shown in Figure 2, the photographs being taken in July 1953. All plots had the same composition in the previous April. The percentages of clover at the fourth cut are given in Table III; these were visual estimations, but they agree well with percentage dry weight of clover obtained by separation of samples taken from time to time.



ABOVE: Unirrigated; without nitrogen. BELOW: Irrigated: without nitrogen.

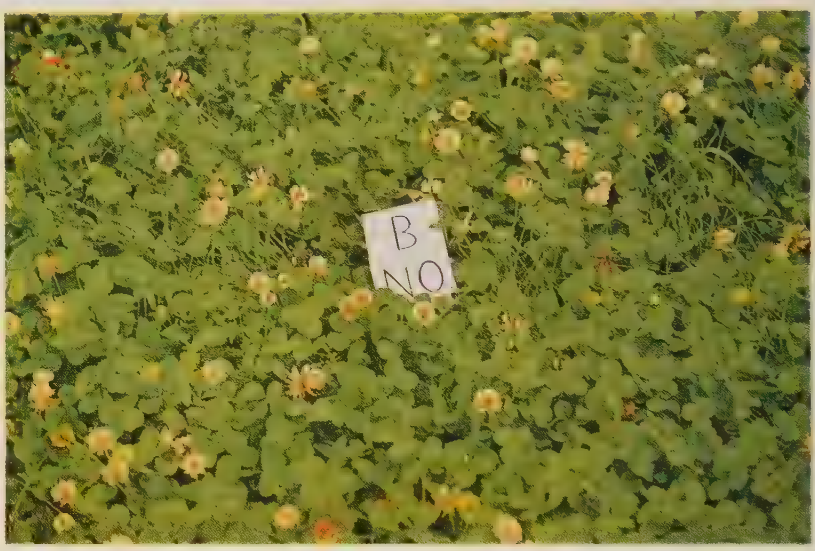


FIG. 2. Effect of irrigation (9 in. water/season) and nitrogen (2·5 cwt. 'Nitro-Chalk'/acre/cut) treatments on the botanical composition of a ryegrass/clover ley, 1953.

The total yields of crude protein in the second experiment illustrate still further inter-relationship of clover, nitrogen fertilizer and water (Table IV). The increase in crude protein for 12½ cwt. 'Nitro-Chalk' as compared with no nitrogen was generally small, especially when the low *p*F range was maintained (0·67 in. deficit). This was clearly because most of the nitrogen was required by the grass where it replaced the clover. In the predominantly grassy sward produced by the lower rate of nitrogen it required nearly all the 12½ cwt. of 'Nitro-Chalk' to give as much crude protein as that in the clovery sward; but, the clover having been replaced, the further 12½ cwt. in the higher rate was available for increasing crude protein. The effects of treatments on dry matter and crude protein are illustrated in Table V.

One of the objects of the irrigation investigation was to find how far it is possible to maintain a steady rate of growth through the season. The histograms (Figure 3) show that the rate of production was more uniform when the water was maintained in a low *p*F range (0·67 in. deficit); nevertheless the spring rate of growth was not maintained.

In the second experiment all the plots were not cut at the same time, but only those for any one nitrogen treatment irrespective of the irrigation regime. As a result, by the end of May, 47·3 cwt./acre had been obtained from the higher nitrogen rate and 40·8 from the lower, whereas the no-N plots yielded only 36·0 cwt. by 5th June when the clover was in flower. These plots were not irrigated.

In *The Calculation of Irrigation Need* [1] it is stated that a deficit of 3–5 in. can be allowed to develop on grassland before there is a marked drop in rate of growth. This did not apply at Jealott's Hill, where the soil is probably not greatly different from that in grassland areas having clay subsoils. Here a deficit of 2·0 in. clearly limited growth.

The forecast of the existence of a deficit of 1·2 in. in the first and 1·34 in. in the second experiment, by application of the Penman formula, agreed very well with its ascertainment by soil sampling, assuming that only the water in the upper 12 in. was available to the grass and clover, the irrigations often being on successive days. The calculation of the deficit by the Penman formula takes no account of the depth of the soil from which water is being taken, so that the close agreement between the two methods suggests

Above: Unirrigated; with nitrogen. Below: Irrigated; with nitrogen.

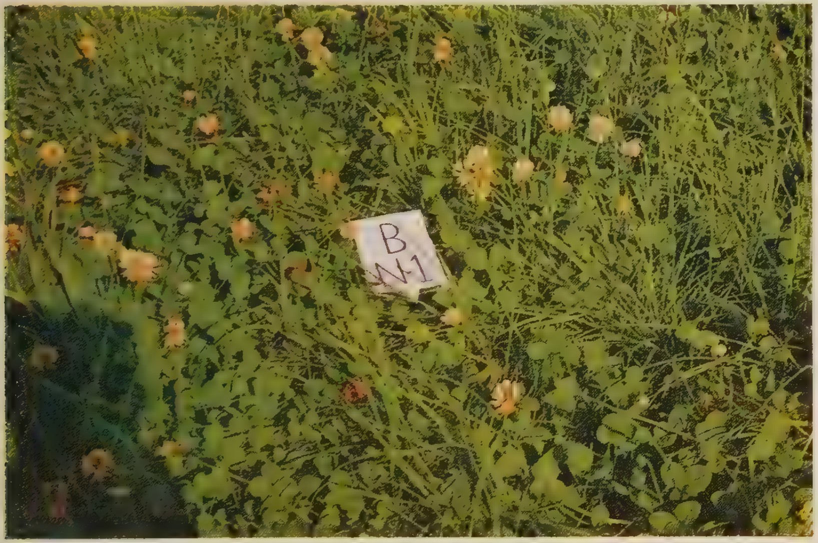


TABLE IV

TOTAL YIELD OF CRUDE PROTEIN (cwt./acre), WITH N AS 'NITRO-CHALK,' 1953

Deficit before irrigation	Rates of N (lb./acre)		
	0	43	86
Unirrigated	12·3	14·5	21·8
2·0 in.	15·0	16·4	22·4
1·34 in.	16·2	17·7	23·7
1·34 in. (Met. data) . .	16·6	19·5	22·5
0·56 in.	17·9	18·5	23·8

Sig. diff. for any two N rates for any one watering treatment: 1·6; for any other pair of results: 2·5

TABLE V

PERCENTAGE INCREASES OVER CONTROL* IN DRY MATTER AND CRUDE PROTEIN, WITH N AS 'NITRO-CHALK' APPLIED OVER SEASON, 1953

Treatment	d.m.	c.p.
Irrigated† only	27	46
N only at 43·5 lb./ac.	31	18
N only at 87·0 lb./ac.	65	78
Irrigated + N at 43·5 lb./ac. . .	54	51
Irrigated + N at 87·0 lb./ac. . .	83	94

* Yield/acre with no N or irrigation: 67·8 cwt. d.m., 12·29 cwt. c.p.

† Irrigations done when deficit 0·67 in.

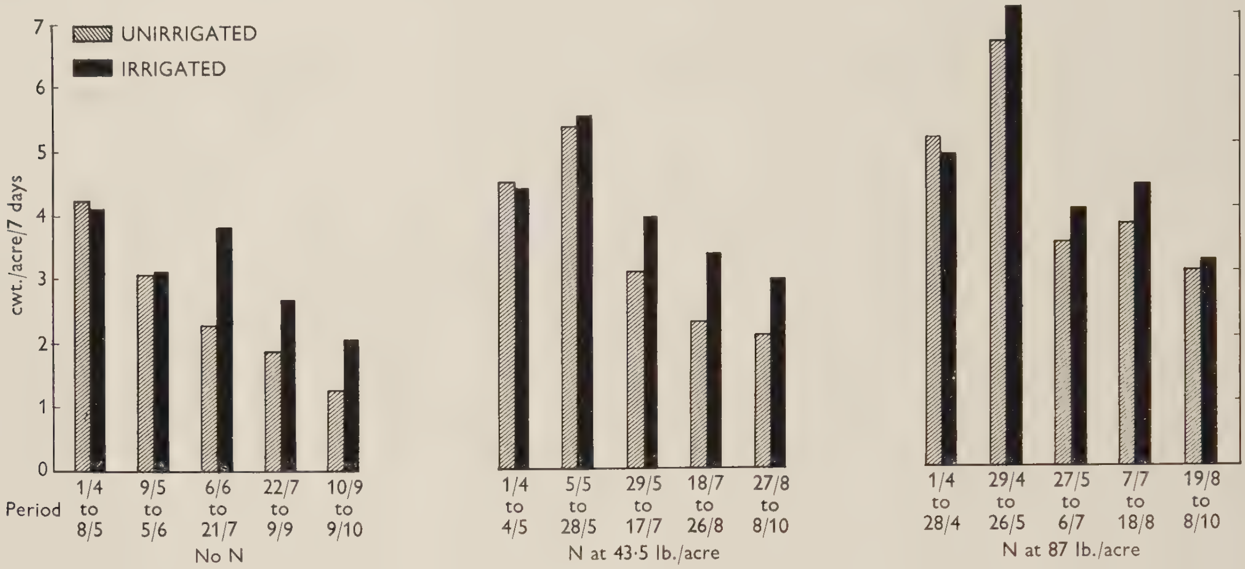


FIG. 3. Rate of production of dry matter with and without irrigation and nitrogen as 'Nitro-Chalk,' 1953.

that little water outside the upper foot was being utilized at Jealott's Hill.

In some of the preliminary investigations evidence of over-irrigation was obtained. In one year, for example, 0·82 in. of rain fell in the 24 hours after restoring plots to field capacity, and at the subsequent cut the yield from the irrigated plot was lower than that from the non-irrigated.

CONCLUSIONS

The following conclusions can only be applied unequivocally to Jealott's Hill, but they would probably hold for corresponding conditions elsewhere.

1. To maintain maximum dry matter production it was necessary to have a plentiful supply of water at low tension, *p*F 2·0–3·34. Nevertheless a *p*F of 3·80 could be allowed to develop without appreciably reducing growth.
2. On predominantly perennial ryegrass swards with a good supply of fertilizer nitrogen a greater deficit could be allowed—*p*F about 4·0.
3. Perennial ryegrass appeared to grow quite vigorously when relatively high *p*F values were allowed to develop, provided there was plenty of nitrogen, whereas white clover did not grow vigorously. When the average *p*F was low, clover became very competitive with grasses.
4. Calculation of the deficit by the Penman method agreed well with that found by measurement in the effective root space of the soil.
5. On plots to which no nitrogen fertilizer was applied, irrigation had a profound effect on the sward composition, the proportion of clover to grasses increasing as the average level at which the *p*F was maintained was lowered.
6. Irrigation helped to even out production over the season, but there were still seasonal peaks.
7. Heavy rainfall immediately after irrigation can lead to reduction in growth. Under field conditions, weather reports need to be consulted before irrigating. It is clearly unwise to restore the water content to field capacity.

ACKNOWLEDGMENT

We thank the editor of *Journal of Agricultural Science* for permission to publish this modified and condensed version of an article which appeared in vol. **52,** pp. 256–62 of that journal.

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SOME NUTRITIONAL AND PHYSIOLOGICAL ASPECTS OF CALF REARING

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A great deal of research work is now being done in the hope of finding better or cheaper methods of calf rearing, and this paper briefly reviews some of the results that have been obtained in studies of the fundamental problems involved. It is concerned essentially with factors that affect the nutrition and development of the calf from birth to weaning, considered in relation to early-weaning systems of feeding now being adopted on many farms.

As in most other fields of agricultural research, a spate of experiments on the nutrition of the calf has taken place since the last war. It will be shown later that some of the results obtained have merely put in scientific terms observations on calves obtained several centuries ago. With new discoveries in pure science, advances have been made in fundamental knowledge relating to the calf, but often the application of this knowledge to practical calf-rearing methods has only led to the revival with slight modifications of methods discarded in an earlier era. Thus there appear to be fashions in calf rearing just as there are fashions in our social life. It seems that quite often a satisfactory method of rearing is established, but as the years go by it is distorted in its repetition by agricultural writers until the method is used under unsuitable conditions and falls into disrepute. A new method arises phoenix-like from the ashes and in due course suffers the same fate.

This article will deal partly with current fundamental problems in calf nutrition and partly with calf-rearing systems.

FACTORS AFFECTING BIRTH WEIGHT

Let us start with the birth weight of the calf. Nutrition of the calf would be very much simplified if the great variation between individual calves within a breed could be reduced. In general, the larger the average mature weight of the breed, the larger the average weight of the calf at birth, the faster is its growth rate and the slower it reaches maturity. The small breeds have calves of small birth weight, fine bone, slow growth rate, but early maturity. The aim of cross breeding for beef production is largely a matter of obtaining the correct mixture of fine bone and fast growth rate, providing no such trait as colour of fat unacceptable to the consumer is introduced.

Within a breed, the variation in birth weight is considerable; for instance in our experience Shorthorn calves vary from about 45 to 125 lb. in weight with an average of about 82 lb. If these weights are divided throughout by 10, it can be seen that the range is very similar to that in human infants. Now it is well known that twin calves are lighter than single ones, and that bull calves, which are heavier when mature, are heavier at birth than heifer calves. It is also pretty clear that bull calves are carried on the average about a day longer before birth and that cows give birth to heavier calves at each successive calving up to about the third, after which time the size of calf seems, if anything, to fall. For heifer calves, a mean difference of 14 lb. in weight has been demonstrated between the first and second calf in a Shorthorn herd, while the difference between the second and third calf averaged 11 lb. [5]. The relationship between the weight of dams and that of their calves, after adjustment for calving sequence, has rarely been found to be statistically significant. Thus, having allowed for all these affecting variables, there is still a large and unaccountable variation in birth weight.

The current opinion is that the genetic make-up of the calf determines birth weight to a far lesser extent than the "maternal environment." It is known for instance that a short dry period under poor nutritional conditions may reduce the birth weight of calves; similarly infant birth weight has been shown to decline with the social status of the parents, but efforts to incriminate a low level of intake of a particular nutrient have not been successful [28]. Although "steaming up" before calving has been shown to increase the birth weight of calves, particularly of those out of heifers, the increase has been small and when adjusted for the increased weight of the dam has invariably been non-significant. It is therefore apparent that ways of modifying the "maternal environment" to alter birth weight of the calf are still largely a matter of scientific conjecture.

FACTORS AFFECTING THE COMPOSITION OF COLOSTRUM

As with birth weight, only a small measure of control is possible over the composition of colostrum, which to all intents and purposes is a mixture of true milk as secreted in later lactation and non-diffusible constituents of blood plasma that have been concentrated some ten- to fifteen-fold in their passage into the udder some time before calving. It used to be thought that this passage into the udder took place gradually once a cow had been pregnant about five months, but prepartum milking (see Figure 1) and isotopic studies indicate that most of this concentrated plasma appears in the udder about 3–9 days before calving [9, 23].

Colostrum is very rich in the soluble proteins, particularly the "immune lactoglobulins," in carotene, and in the fat-soluble and the majority of water-soluble vitamins. Of the constituents of colostrum, only the non-protein nitrogen, the fat-soluble vitamins and certain minerals can be increased by feeding supplements before calving. Efforts to increase the soluble protein content of colostrum by feeding high-protein rations before calving have only led to an increase in the non-protein nitrogen fraction. Some method of control of the protein content of colostrum might be desirable, for there is some indication that mammary oedema, which may result from the removal of the non-diffusible constituents and water from the plasma just before calving, is related to the content of protein in the colostrum. Additional vitamin A given before calving increases the amount in colostrum, which when ingested increases the liver reserve of the calf. In addition the plasma level of vitamin A and the liver reserves of the calf, born of vitamin A supplemented cows, are greater than those of calves born of unsupplemented cows. Similarly, feeding of vitamins D and E before calving will increase the content of these vitamins in colostrum, while the prepartum feeding of cobalt has increased its content in colostrum a hundred-fold.

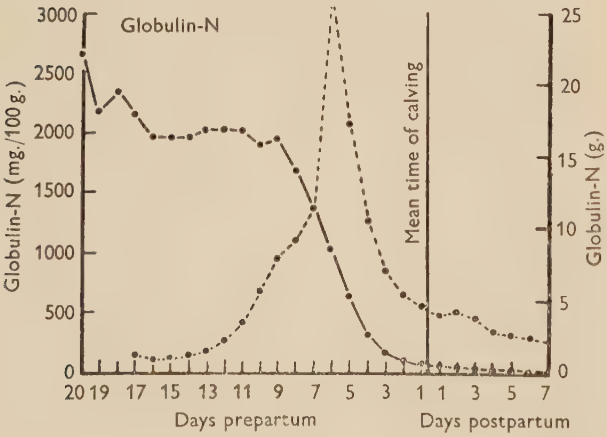

FIG. 1. The effect of prepartum milking on the content of globulin-N in the secretion.
Percentage ●——●. Weight ●- - - -●.

THE TRANSFER OF PASSIVE IMMUNITY

During the first 24 hours of life, the "immune lactoglobulins" ingested by the calf are taken up by the epithelial cells of the small intestine, pass into the lymph spaces and then into the blood circulation by way of the thoracic lymph duct. Recently it has been shown that not only the "immune globulins" but also the other whey proteins of colostrum can pass into the blood stream, although the latter appear to be soon excreted by way of the urine [2, 7]. Why the epithelium of the small intestine should allow the passage of these large protein molecules during the first 24 hours of life and for little longer, is a mystery that has puzzled scientists for the last thirty years. There are two main theories which are not mutually exclusive; firstly, that absorption at this time is permitted owing to the absence of enzymes that would normally degrade the protein to simpler compounds like polypeptides and aminoacids; and secondly, that during this early period of life the intestine is in fact more permeable. In favour of the former theory is the finding that, in lambs at least, the parietal cells that produce hydrochloric acid in the abomasum are not fully developed during the first 24 hours of life, and therefore the whey proteins exuded from the casein clot may escape degradation [10]. Moreover, colostrum contains an anti-tryptic enzyme which might be expected to protect the whey proteins from the action of the proteolytic enzymes of the pancreas. This theory has not been yet substantiated, for when the enzymes have been inactivated in older calves no passage of globulins occurred on feeding colostrum. Similarly, the placing of massive amounts of colostrum directly into the small intestine, with the intention of by-passing the abomasum and swamping the enzyme activity in the intestine, was without avail in allowing globulin passage [27].

Attempts to increase the period of permeability of the small intestine have also met with no success. Various hormones, including stilboestrol, progesterone, a combination of the two, cortisone and A.C.T.H. (adreno-corticotrophic hormone), given in various ways, have been tried; so also has the feeding of amniotic fluid and nucleic acids [7]. Another factor which may be of importance is the development of the bacterial flora in the intestine soon after birth, for it is known that thickening of the wall occurs as a barrier against bacterial invasion.

If a guess may be ventured, it would seem that the increased permeability of the capillaries in the udder to the passage of globulins from the blood stream into colostrum may well be brought about by the same factors that allow the passage of globulins into the blood stream in the new-born calf; this would strongly suggest a hormonal effect.

HORMONAL STATUS AT BIRTH

There is little doubt that new-born calves are very much under the influence of a high level of sex hormones at birth. Thus, their teats are large in size but decrease rapidly with age, a decline that can be prevented by the feeding of oestrogens. Colostrum is also oestrogenic [18] but it is not known whether the oestrogens are present as a result of their passage from the blood stream concomitantly with the passage of globulin, or whether colostrum is a vehicle for the excretion of small amounts of oestrogenic metabolites. Certainly, colostrum ingestion is not a factor in causing increased teat size, as the phenomenon also occurs when calves have been given only very small amounts of colostrum. However, the oestrogens in colostrum may have a physiological effect, since quite small amounts of synthetic oestrogens will increase the size of the accessory sex glands even as early as the first three weeks of life. Moreover, the calf appears to be strongly under the influence of thyroxine at birth, for the pulse rate is very high during the first few days of life as is the level of plasma protein-bound iodine [14].

Escherichia coli INFECTIONS

Most of the constituents of colostrum, present in high concentration, are of importance to the calf, since, before suckling, blood levels and liver reserves of many of these constituents are low. For instance, the calf has negligible amounts of "immune globulins" in its blood stream before suckling, and these are of particular importance because they confer passive immunity to the calf against many potential pathogens in its environment, particularly *Escherichia coli.* Nevertheless, if calves are kept alive without colostrum they gradually synthesize their own immune globulins during the first month of life.

Two different but closely associated conditions of *Escherichia coli* infection afflict the new-born calf. The first, a septicaemic condition with coliform organisms present throughout the tissues of the body, is nearly always restricted to calves that have been deprived of colostrum and death usually occurs at 2–3 days of age. It is presumed that the organisms gain access through the permeable wall of the small intestine. A rather heterogeneous collection of coli strains tends to cause this condition and, from our experience, colostrum usually contains antibodies against them [12].

The second condition, a localized intestinal infection with *E. coli*, is no doubt the most important cause of calf mortality on farms today. The coli multiply in the small intestine, in which they form a carpet-like layer; they do not invade the tissues of the calf further than the mesenteric lymph nodes, but the calf scours badly and eventually succumbs to dehydration, usually when 7–14 days of age.

This second condition is often associated with intensive calf rearing methods, in which large numbers of susceptible young animals are continually passed through a calf house. Just as in intensive chick rearing methods *Clostridium welchii* type A seems to depress performance, so in the calf and probably in the human infant *E. coli* organisms tend to depress performance under crowded conditions [13, 24]. Figure 2 shows the increase in mortality in calves that occurs throughout the calving season; at one time the higher losses in the late spring months were thought to be due to the low vitamin A level of the dam's diet in late winter and early spring, but this has never been substantiated. The *E. coli* localized intestinal infection is associated with particular strains of coli which seem to increase in virulence as they pass through a number of calves. Unfortunately, there is no satisfactory method of differentiating between pathogenic and non-pathogenic strains of *E. coli*, for this bacterium is, of course, a normal member of the flora of most animals. However, strains of coli isolated from calves suffering from white scours do tend to be mucoid, and it is possible that the release of this large quantity of mucous antigen in the lumen of the intestine may be important in causing irritation and scouring [22]. As no invasion of the tissues occurs, the actual cause of death is still not known, but

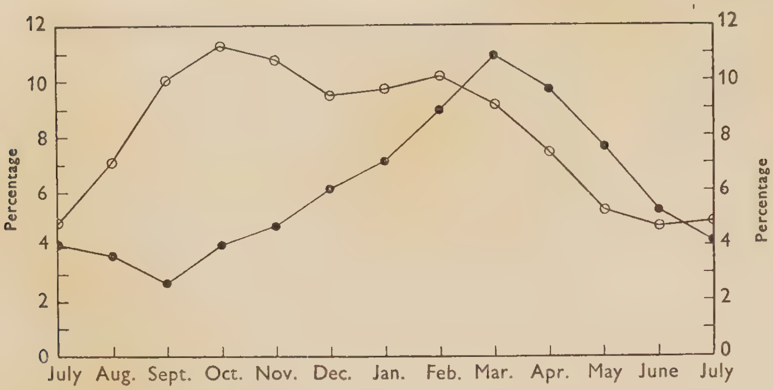

FIG. 2. Relationship between mortality rate and month of year. ○——○ percentage of total births that occurred each month; ●——● percentage of calves born alive that died each month.

recently we have found that calves dying from this condition show serum potassium levels that are normally considered toxic, and it is possible therefore that the sequence of events resulting in death may be a toxic level of serum potassium owing to dehydration, which occurs as a result of profuse scouring. At this point the investigator is rather in a dilemma, for it is not known whether scouring is a consequence or a cause of the multiplication of the organism. Be that as it may, it is clear that some predisposing cause must be present.

PREDISPOSING CAUSES AND CONTROL OF SCOURING

Without doubt the main predisposing cause of scouring is the quality and quantity of the diet given after the colostrum-feeding period. If too little colostrum is fed the trouble is liable to occur, and the risk of it is greater if a milk substitute is fed than if the diet is whole milk.

Heat Treatment of Milk By-products

Milk substitutes are in general based largely on dried skim milk powder, but there are great differences in the performance of calves given milk substitutes containing reconstituted spray-dried skim milk powders that have been subjected to different heat treatments. Not only is there a higher mortality from coliform infections with inferior powders, but even when no clinical symptoms of scouring are apparent, growth rate is greatly depressed; this depression may be as much as 30% during the first fortnight of life. The poor quality is associated with the denaturation of about 50% of the whey proteins, and with the formation of a different type of clot by the action of rennin in the abomasum, probably owing to changes in the solubility and ionization of the calcium. It is of interest that as long ago as the late eighteenth century it was common practice to have a lump of chalk hanging up in the calf pens to prevent scouring on skim milk diets.

Studies in the U.S.A. before the last war have shown that whole milk leaves the abomasum faster than skim milk, and that boiled milk takes longer to clot than raw milk. Moreover, although boiled milk is broken down at the same rate as raw during the first 3–6 hours after feeding, thereafter it is broken down much more rapidly. The rate of emptying of the abomasum has been found to be about 9½ hours for a litre of raw skim milk compared to 6¾ hours for a litre of heat-treated skim milk.

Although there is clearly a detrimental effect of certain heat-treated milks on the well-being of the calf, the mild heat treatment of pasteurization has no harmful effect. On the other hand, the U.H.T. sterilization of milk (275° F. for 1–3 sec.) does damage the milk as far as the calf is concerned, for this process seems to denature about 50% of the whey proteins.

Contamination of Milk

Another possible predisposing cause of scouring is the presence of pathogenic coliform organisms in the milk given to the calves. Recently, Thompson [29] has shown that 1% of samples of raw milk from farms contained strains of *E. coli* associated with infantile gastroenteritis, and although the antigenic types which commonly affect babies are rare in calves it seems that contamination of the milk may well be of importance.

Quantity of Diet

The volume of the diet offered, especially during the first fourteen days of life, can also influence the extent of digestive disorders: the greater the amount, the more the risk. Table I shows the amount of milk required for given growth rates of young calves; these are average values for the first three weeks of life, for in fact the calf has a very much higher energy requirement for maintenance after birth than at, say, three weeks of age. Figure 3 shows the basal heat production of calves during this period. It increases to a peak value on the second to fourth day of life and then falls

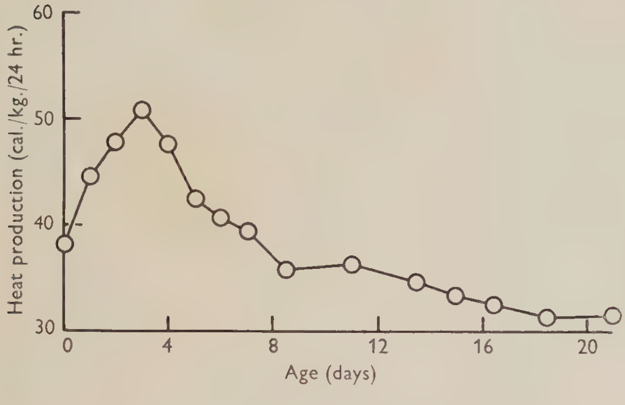

FIG. 3. Mean heat production of four calves.

slowly; these changes may be the result of the calf's efforts to adapt itself to its new environment, as it is known that the body temperature of the calf does not reach its highest value (which is higher than that for an adult cow) until the second day of life. The higher energy content of colostrum than of milk may be necessary to cover the high energy requirement of the calf over the first few days of life.

It is quite possible that, in future, the use of tranquilizing drugs may reduce the volume of milk required by the calf. The idea is not new, for an expedient used in the eighteenth century was as follows: "balls made of wheat flour, and a sufficient quantity of gin to form it into a paste, are given them; three balls, about the size of walnuts, being given about a quarter of an hour after each meal. The effect is that, instead of wasting themselves by incessant 'bawling,' they be quiet; sleeping a principal part of their time" [15].

TABLE I

WHOLE MILK REQUIREMENT FOR VARIOUS LIVE-WEIGHT GAINS OF CALVES OF DIFFERENT BIRTH WEIGHTS

Live-weight gain (lb./day)	Milk requirement (pt./day) of calf of birth weight		
	60 lb.	80 lb.	100 lb.
0	3·8	4·8	5·9
0·5	5·1	6·2	7·2
1·0	6·5	7·5	8·6

Control by Antibiotics

Luckily, these scouring conditions associated with *E. coli* can generally be controlled by the tetracycline antibiotics, and in an emergency, when colostrum is for some reason unavailable, tetracycline antibiotics given immediately after birth and for the next ten days of life will ensure practically as good a protection as colostrum. The overriding worry about the routine use of antibiotics is the fear of the development of resistant strains. There is no gainsaying that strains of coli isolated from calves given fairly large amounts of antibiotic (125–250 mg./day) are more resistant to the antibiotic than those isolated from calves not given an antibiotic, but this is to be expected. The real problem is whether the resistant strains are more, or less, pathogenic than the non-resistant, and, if they are pathogenic, whether any other form of economic chemotherapy is available to deal with them. There is a scarcity of information on the subject. Later in this paper mention will be made of the use of antibiotics in the young ruminant calf.

MILK SUBSTITUTES

Carbohydrate Content

Although the replacement of marketable milk by milk substitutes for use directly after the colostrum-feeding period has become widespread, the composition of these substitutes has been largely empirical. The importance of the quality of the mainstay, namely dried skim milk, has already been discussed, but the crux of the problem lies in the replacement of butterfat, removed at separation, with some alternative source of energy.

Some substitutes contain cereal products, such as oat flour, and it seems that these are sometimes used directly after the colostrum-feeding period. Such gruels based on liquid skim milk were used commonly in the eighteenth century, but never before the third week of life. Their use before this age is pointless nutritionally, although the flour may have a costive effect, for it has long been known that calves of a week old are unable to digest starch or even dextrinized starch. More recently it has been demonstrated that even if starch is degraded to maltose it is unavailable to the calf, as is also sucrose [8]. In fact, only lactose and glucose appear to be of use to the young calf, and even these cannot be included in sufficient quantity to replace the calories removed in the fat, without causing digestive disorders. This phenomenon appears to be due to the very low enzyme

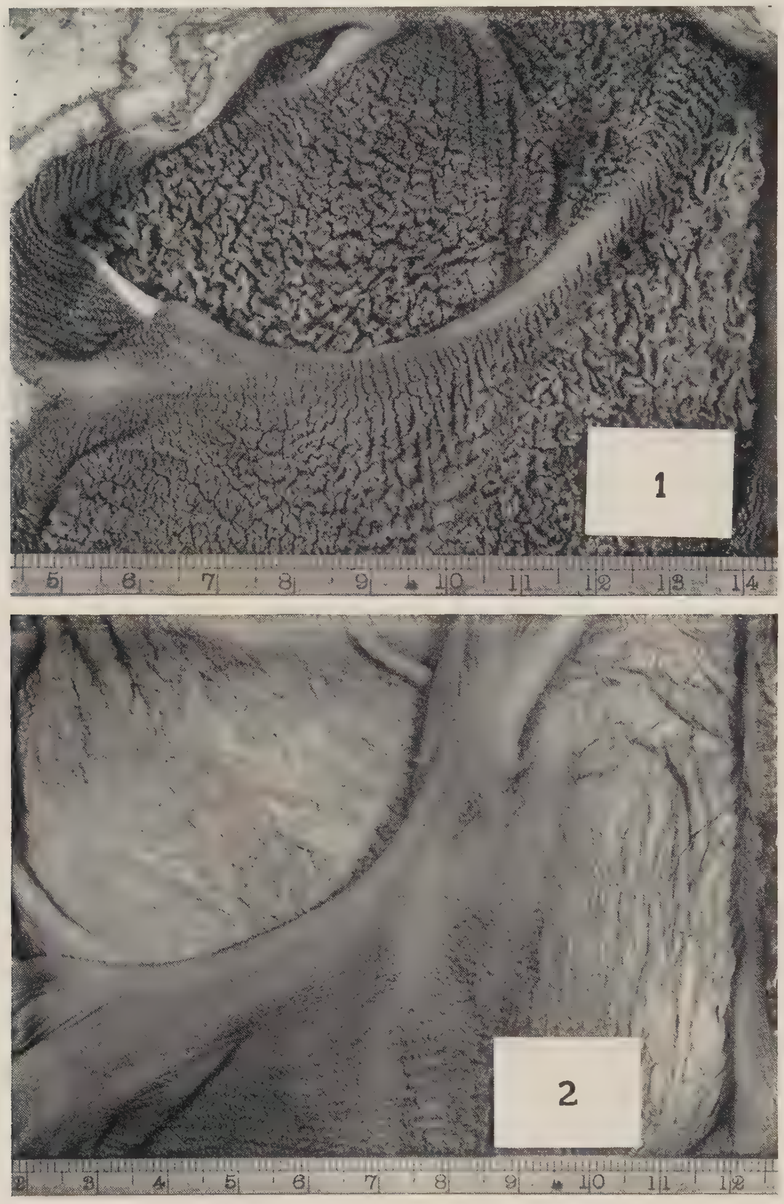

FIG. 4. Papillae development in the ventral blind sac of the reticulo-rumen of two 12-week-old calves. Calf No. 1 had eaten 66 lb. of barley and 15 lb. of hay; calf No. 2 had eaten ½ lb. of barley and 55 lb. of hay.

activity, both of amylase from the pancreas and of maltase and sucrase from the intestinal mucosa, during the first four weeks of life.

Fat Content

The alternative to the addition of carbohydrate, either as sugar or in the form of dried whey, is the use of vegetable fat. Although the addition of fat is quite feasible under experimental conditions, it is beyond the resources of the farmer because, unless correctly emulsified or homogenized, such diets cause profuse diarrhoea. However, the use of the phospholipid, lecithin, may make homogenization unnecessary. Table II shows the marked effect that lecithin has on the absorption of the fat-soluble vitamin A by the calf, and recent work from America has shown that the addition of lecithin to coconut fat rendered the fat as digestible as that in a similar diet in which the fat had been homogenized [11]. If this finding is confirmed, the preparation on the farm of milk substitutes containing as much fat as whole milk may become a practical proposition.

In past experimental work the inclusion in milk substitutes of fats containing a high proportion of unsaturated fatty acids, even when fats have been homogenized, has often proved unsatisfactory, and in general hydrogenation of the fats produces a marked improvement in performance. The feeding of highly unsaturated marine oils and lard is associated with muscular dystrophy, for a diet devoid of vitamin E rarely produces this condition in the absence of a source of unsaturated fatty acids [4].

We have been unable at the N.I.R.D. to demonstrate any difference in the performance of calves given butter fat or margarine. Recent work, however, has shown that the digestibility of hydrogenated palm oil between nine and sixteen days of age was lower than that of butter fat [21]. This finding is in keeping with the results of Canadian workers, who have shown that at least for piglets, young guinea-pigs and pups, the digestibility of a fat can largely be accounted for by the length of the constituent fatty acid chains rather than by their saturation; that is, the shorter the fatty acid chain, the greater the digestibility.

Veal Production

No form of dry feeding has yet been used satisfactorily for the production of high-quality veal at 10–12 weeks of age. Veal can be produced, however, by the use of large amounts of fresh or reconstituted skim milk supplemented with fat-soluble vitamins although such a diet is excessively rich in protein. It would be expected that deamination of the excess amino-acids, derived from the protein, would make sufficient energy available to give results as good as with whole milk, for deamination produces two-carbon fragments which are precursors of fatty acids and thus of fat. In fact, the results are usually disappointing in spite of the finding that isocaloric diets with fat contents varying from 2–4% have given no difference in growth rate.

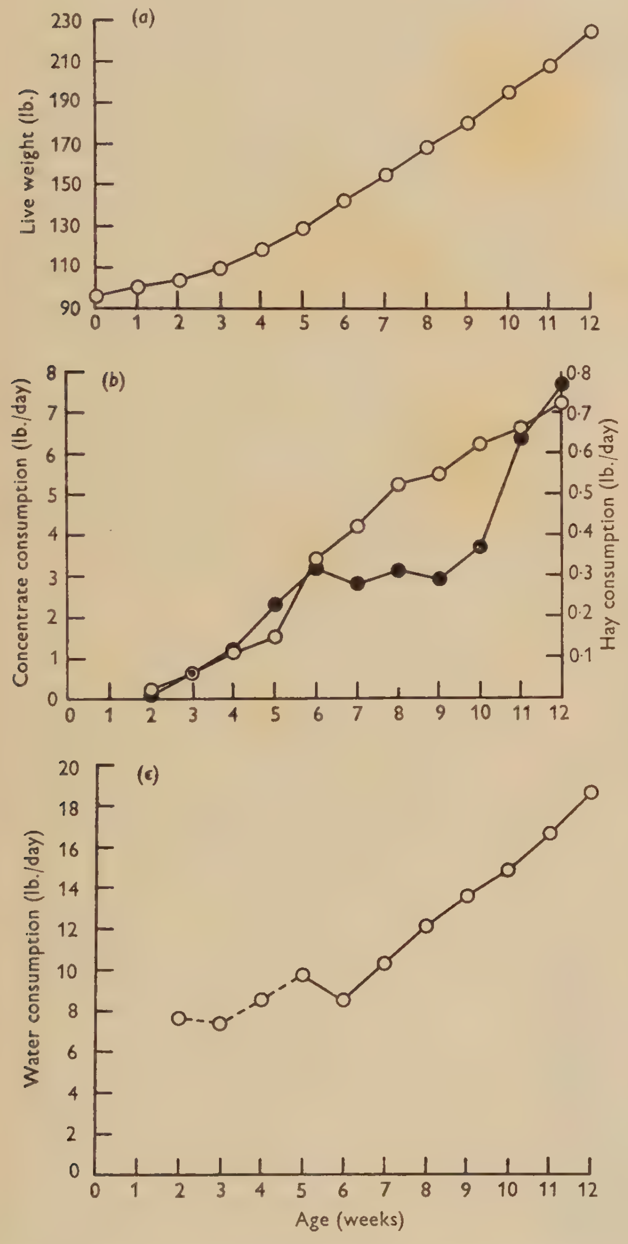

Fig. 5. Data of Friesian calves weaned on to dry food *ad lib.* at 5 weeks of age.

(*a*) Growth rate.
(*b*) Concentrate (○——○) and hay (●——●) consumption.
(*c*) Water consumption (○——○), including water present in milk (○- - -○).

TABLE II

EFFECT OF LECITHIN ON THE LIVER RESERVES OF VITAMIN A AT 21 DAYS OF AGE

Initial feed after birth	Liver vitamin A at 21 days (total i.u.)	
	Exp. 1*	Exp. 2
80,000 i.u. vit. A . .	8831	775
10 g. lecithin+ 80,000 i.u. vit. A	15310	1581

* In Exp. 1 only, vitamin A was fed daily as well as in the initial feed.

DRY FEEDING

The Early-weaning System

The early-weaning system of calf feeding, in which the quantity of the liquid diet is reduced to a minimum, has recently been developed at the Rowett Research Institute [19], and with some slight modifications has been recommended by many feeding stuff manufacturers. Experiments on such a system were done in the 1920s in the United States, but owing possibly to lack of economic pressure the idea came too early to be taken on by the farming community. During the last few years, however, economic pressure together with intensive advertising of the system has led to its adoption on many farms.

As generally advocated the calf is given just enough milk to cover its requirements for maintenance and $\frac{1}{2}$ lb. gain daily (see Table I) or about six pints daily up to five weeks of age, at which time the milk is usually stopped abruptly. A concentrate mixture made palatable, usually by the inclusion of molasses, and the reduced milk intake are the main factors that result in an increased dry food intake during the early weeks of life. With calves of large birth weight, daily weight gains of 2 lb. may be achieved from the fourth week of life, although before this age growth rates are considerably lower. Figure 5 shows some results for Friesian calves weaned at five weeks of age and given concentrates and hay *ad lib.* Large calves weaned at three weeks of age show very much the

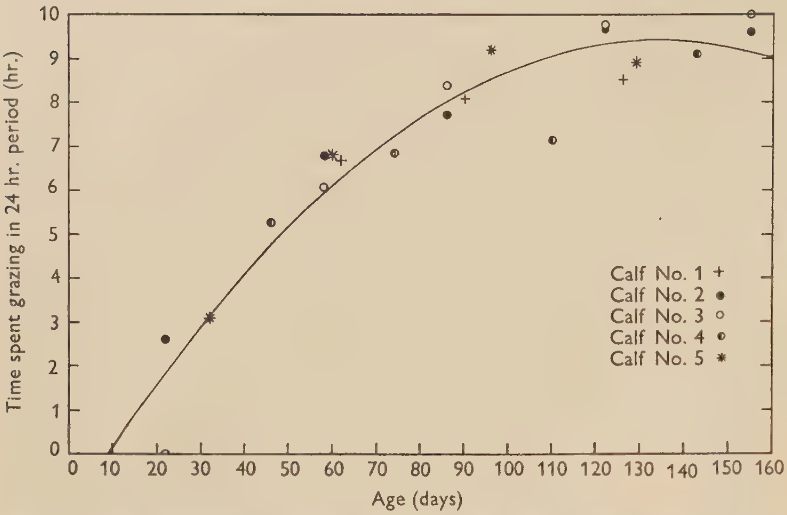

FIG. 6. The relationship between age and the time spent grazing in a 24-hr. period.

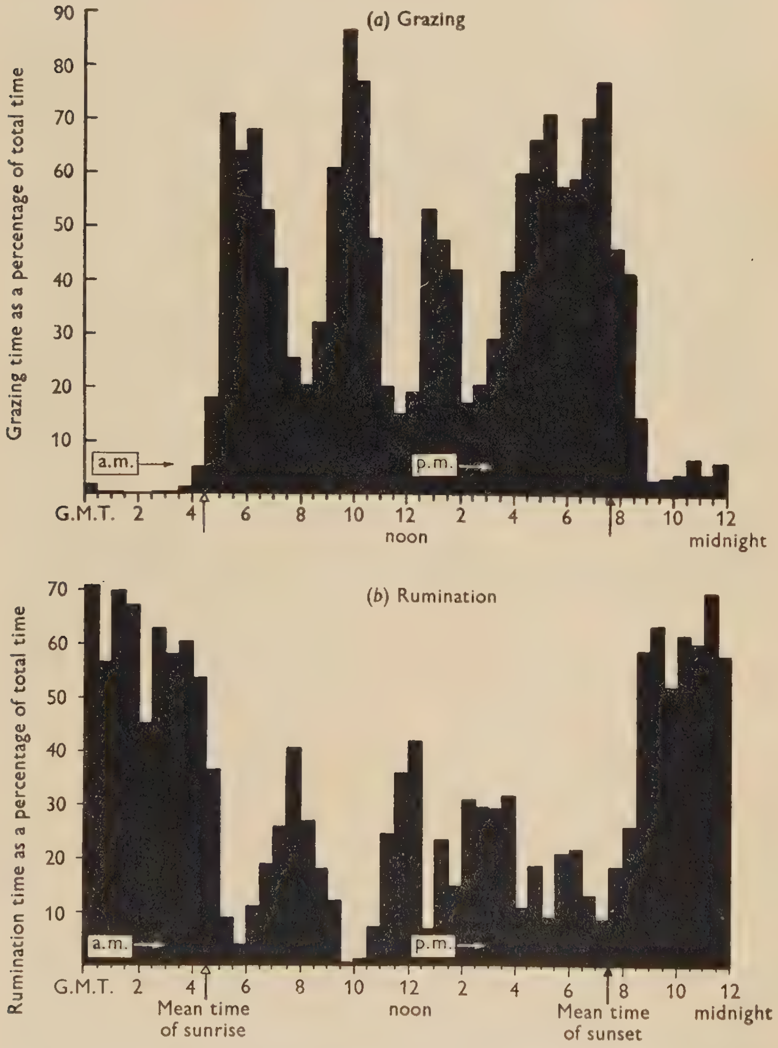

FIG. 7. The distribution of grazing and rumination throughout the day (mean of five monthly observations).

same general picture, but calves of the smaller breeds weaned at this earlier age usually show a slight setback at weaning. Since the average weight of the calves given concentrates *ad lib.* in our experiment was 225 lb. at twelve weeks, and since with the highest plane of nutrition possible they probably would not have weighed more than 260 lb. at this age, there seems to be little justification for the continued use of suckling methods except for veal production and for calves of pure beef breeds which are usually small at birth. Small calves, to gain rapidly, need to ingest 2–3 gallons of milk daily, for they can consume much greater amounts of dry matter daily as milk than as concentrates. The use of tetracycline antibiotics in the concentrate mixture (8 mg./lb.) has been shown to increase food consumption, and it is suggested that this is a result of reduced fermentation in the rumen with a consequent lowered gas production [20].

The Grass System

Another method which has received particular attention recently is the weaning of calves at an early age on to grass rather than concentrates. It is a sobering thought that, according to Trow-Smith [30], as long ago as 1573 Thomas Trusser recommended that calves should be weaned on to grass at 50 days of age, while Mortimer in 1716 [16] recommended that calves should be turned out at Lady Day (March 25th) and that milk should be given outside from a pail up to twelve weeks of age (see also Pitt, 1809 [17]). His advice continues as follows: "But by no means let your grass be too rank, but short and sweet, that they may get it with some labour. All wean their calves at grass; for if you wean them in the house with hay and water, it is apt to make them big-belly'd and to rot."

Although growth rates of the order of 1·3–1·5 lb. daily during the first six months of life can be obtained by this method, additional concentrates have to be fed if gains of 2 lb. daily are to be achieved. Most trials have been done with milk substitutes given for 8–12 weeks, and thus the labour costs are probably higher than for early weaning indoors. But food costs are lower, and it seems possible that a compromise between the two systems may be the most economic system for spring-born calves; that is, the calf should be weaned on to dry food indoors and be put out at about six weeks of age.

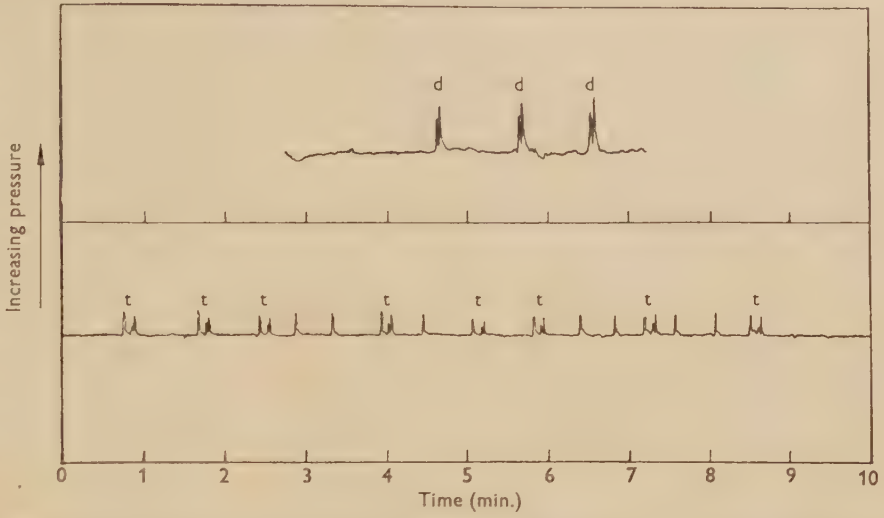

FIG. 8. Pressure changes in the reticulum of a Shorthorn calf at 4 days of age. Double contractions (*d*) above; triple contractions (*t*) below.

This presupposes that calves would do as well under this system as they would if outside from birth, but one of the advantages suggested for rearing calves out of doors from birth is the development of immunity against internal parasites brought about by the ingestion of gradually increasing amounts of grass and thus of parasites. Immunity against coliform infections seems to develop during the first few weeks of life, and immunity to parasites may also occur at this time when calves under the compromise system would still be indoors.

The age at which calves start eating grass is very similar to that for concentrates, as can be seen from Figure 6, showing the relationship between age and time spent grazing. For every hour spent in grazing a similar but slightly shorter time is spent in rumination; the distribution is shown in Figure 7. Grazing seems to start at about 5 a.m. G.M.T. irrespective of the time of sunrise, and to end about one hour after sunset [25].

Rumen Development

Paralleling the development of early weaning, increased interest has been shown in the study of rumen development. A description of adult ruminant digestion has been given in this journal by Balch [1] and remarks here will be restricted to aspects that are particularly apposite to the initiation of rumen function.

There is little doubt that the various muscular contractions of rumination can be stimulated soon after birth by the presence of solid matter in the reticulo-rumen. Similarly, recording balloons in the rumen have been shown [26] to stimulate rumination in the two-week-old calf; some results obtained at the N.I.R.D. in a four-day-old calf are given in Figure 8.

It has long been known that in calves having access to roughages but little concentrates the capacity of the reticulo-rumen is much greater than it is in calves given no roughage, owing to stretching of the rumen walls. A modern reference to this finding is Blaxter, Hutcheson, Robertson and Wilson [3], but writing in 1773 Varlo [32] observed that "cattle have large bellies from several causes. First from the food being barren of richness enough to satisfy the appetite, by evaporated matter, as aforesaid; therefore the creatures are spurred on (as it were) by the cravings of appetite, to eat a great deal, till they swell the belly, and stretch the skin to a great size, in order that out of abundance of gross matter, they may distil the more refined matter to satisfy their cravings, for nature always speaks for itself." The term "evaporated matter" refers to an abundance in concentrates of "rich oily spirits" which "evaporates into the body and satisfies the cravings of nature, though the bowels be left almost empty; cattle which live on such rich food, have generally small bellies."

The development of the rumen papillae, which increase the effective surface area through which absorption of nutrients, particularly the volatile fatty acids, can occur, seems to be related to the amount of potentially absorbable material in the rumen; thus concentrates have a more marked effect than hay [6, 33]. This development is therefore to a large extent in the hands of the farmer, but not entirely so. Figure 4 shows the papillae development in the posterior ventral blind sac of the reticulo-rumen of two calves aged twelve weeks offered the same amount of skim milk, crushed barley, hay and water; the calf with the well-developed papillae ate 66 lb. crushed barley and 15 lb. hay, while the other ate ½ lb. crushed barley and 55 lb. hay.

Before considering future trends, one more "flash-back" may be given on the present fashion for slatted floors for various classes of livestock, including calves. Tuke in 1800 [31] states that calves "are usually kept loose in a house, some of which have a loose-boarded floor, or the boards nailed at a small distance from each other, so as to admit the wet more readily to drain away: this is bedded with straw; and they are thus kept dry and warm, which is found to contribute greatly to their health, and promote their thriving."

THE FUTURE

It is always dangerous to predict future trends, but it is clear that any method that increases production per man hour will gradually become established. At the moment, exploitation of the ruminant method of digestion provides the greatest possibility of saving labour; it can be used for nearly all types of calf rearing except that for veal, and even for this there is the prospect of developing a dry food that can be digested in the rumen and produce "white fleshed veal." Whole milk, however, is still nutritionally the best diet for the production of veal, though the worst economically.

A long period of milk substitute feeding is rather out of fashion, but milk substitutes based on cheap ingredients may yet be evolved and, with the mechanization of liquid diet feeding, prove cheaper per unit of net energy than dry food digested in the rumen. For although the rumen is of value for its capacity for digesting cheap food, the lower digestibility of such foods compared with that of liquid diets based on milk by-products, and the high heat increment and consequent low net availability of the metabolizable energy of food digested in the rumen, must be borne in mind. Such a swing back to liquid feeding in the future is not beyond the bounds of possibility. *Plus ça change, plus c'est la même chose* would seem to be as appropriate to the evolution of new calf-rearing methods as it is to other lines of human endeavour.

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CONTROL OF FUNGAL DISEASES OF FRUIT IN STORAGE

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Spoilage of fruit during transport and storage presents many complex problems. So varied are the conditions under which the fruits have to be kept and so numerous the organisms responsible for decays that several different methods are needed to ensure successful preservation. Among these the use of organic chemicals in dips, skin coatings and wraps is proving to be of great value in reducing losses between the orchard and the market.

The burden of ensuring a maximum marketable yield from the cultivation of fruit falls on both farmer and distributor, and the two aspects of the problem are essentially similar. In the orchard the fruit may be attacked by insect pests and fungal pathogens; after harvesting it is susceptible both to pathogenic and saprophytic moulds, with insect attack of negligible importance. The saprophytes gain a foothold only when the fruit is bruised or damaged, generally by careless handling during picking or packing, but also when the surface has become weakened or broken down by a primary invasion by fungal pathogens.

Perhaps the major proportion of fruit losses from decay may be attributed to the spread of pathogenic fungi, present even before harvesting, and able to grow on healthy, undamaged fruit, however carefully it may be gathered and packed. Even when the initial damage done by such fungi is small, a secondary invasion by harmful saprophytes through the lesions caused by the original infection will extend the damage until the whole of the fruit is rotted. Although some decay fungi can achieve this within a few days the process is frequently a slow one and the extent of the rot then depends upon the conditions under which the fruit is stored: its temperature, ripeness, soundness, and the humidity of the air around it. With rots that are able to spread from fruit to fruit the spacing within the containers is also of major importance.

In earlier times the greatest need was to ensure that the fruit came from the tree in the best possible condition, for with local buyers and a restricted luxury market there was little demand for long storage. Now, as urban populations have increased and transport over thousands of miles has become the only way of meeting an upsurging consumer demand, the preservation of stored fruit has attained an equal importance with its cultivation on the tree.

Although methods of conserving fruits through long periods of storage have been known from biblical times no serious attempts were made until the beginning of the present century to improve the keeping quality of fresh fruit. Much of the pioneer work aimed at reducing wastage of picked fruits in the intervals between harvesting and consumption was carried out in America, where long distances between orchards and population centres accentuated losses from decay. In 1900, Dr. William Taylor demonstrated the value of refrigeration in transporting apples and oranges from western fruit farms to eastern markets and so paved the way for the rapid expansion of the industries in California and Florida.

Spoilage during transport and storage still presents many problems at all stages of handling between producer and consumer. In the United States Wiant and Bratley [26] analysed market inspection certificates over a seven-year period and found an average loss for all varieties of fruit of 2·1%. Since this includes fruits reaching

TABLE I

EFFECTS OF ADVERSE TRANSPORT CONDITIONS ON FRUIT DECAYS WITHIN THE U.S.A. PERCENTAGE LOSSES WHEN (*a*) TRANSPORT IS PROLONGED AND (*b*) CLIMATE IS UNFAVOURABLE

(Data from Wiant and Bratley [26])

Fruit	Transport prolonged	Climate unfavourable
Apple	4·7	4·0
Apricot	0·9	3·7
Cherry	2·2	6·2
Grapefruit	5·4	2·7
Grape	3·4	10·9
Orange..	1·5	1·8
Peach	10·0	3·5
Pear	0·9	2·8
Plum	0·5	3·0

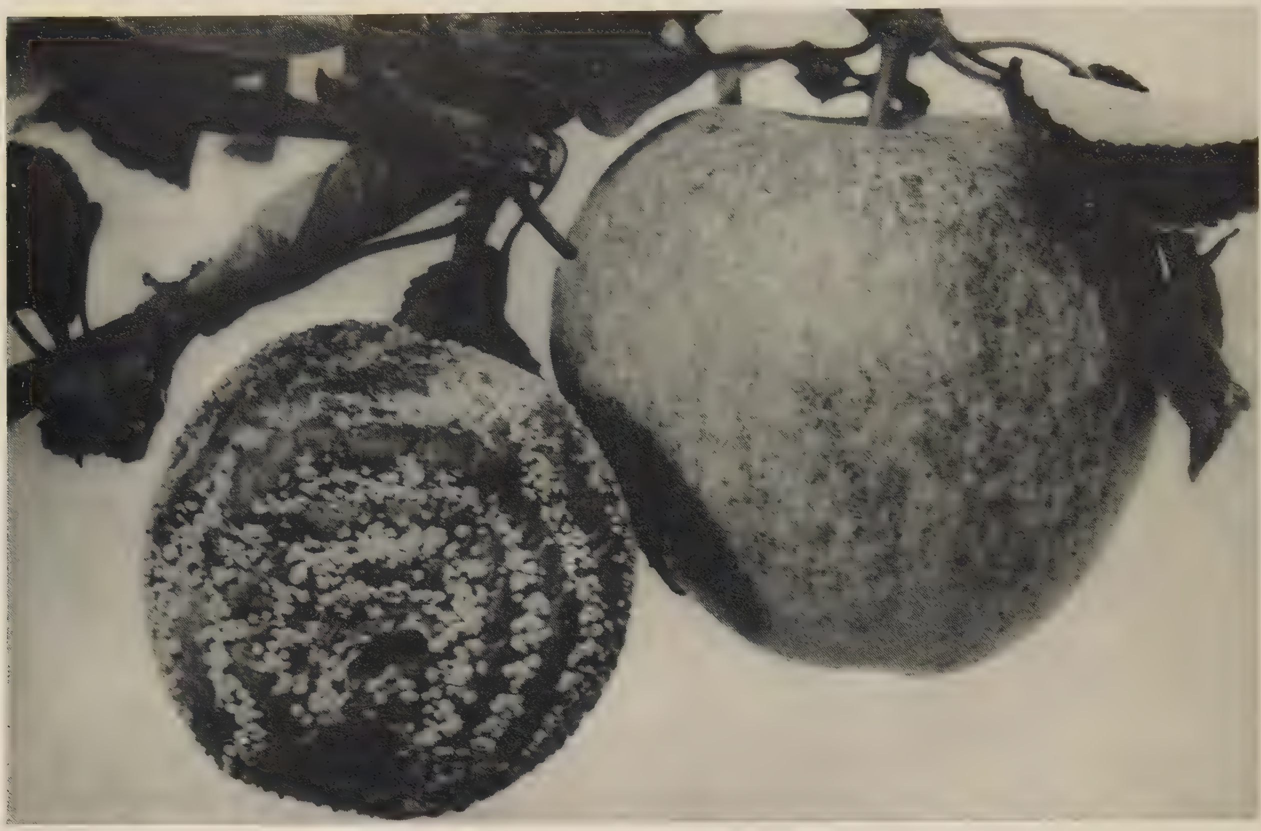

FIG. 1. Brown rot of apple, caused by *Sclerotinia fructigena*. The hole at the base of the left-hand fruit (probably a codling wound) was the point of entry. Note concentric circles of spores.

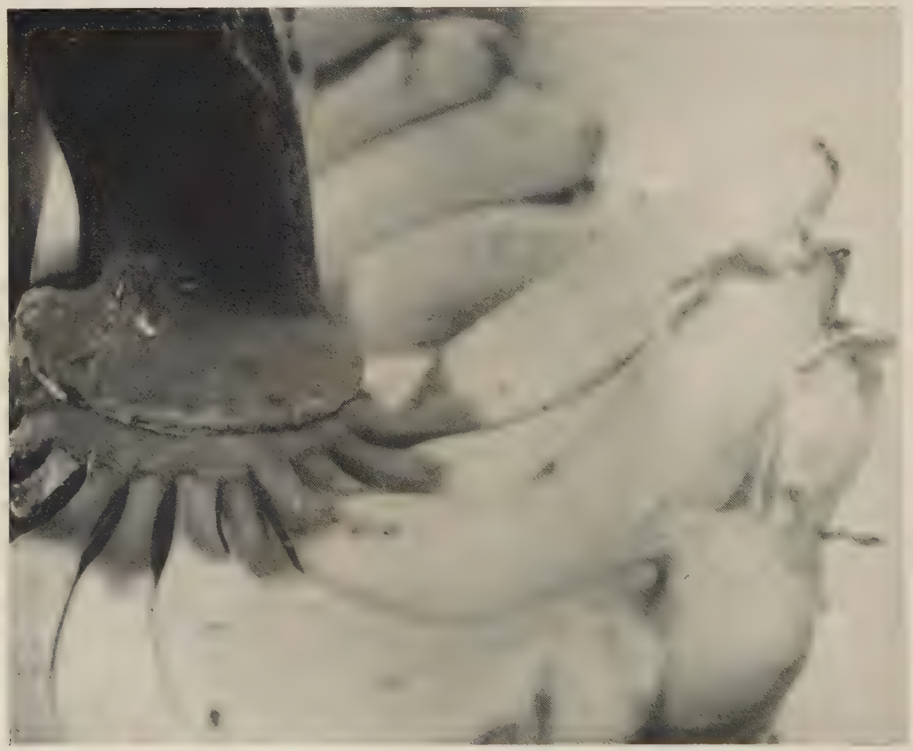

FIG. 2. Pronounced attack of pink rot of bananas, caused by *Glomerella cingulata*.

the markets from both local and distant growers and fruits that travel both well and badly, a better idea of the losses that may arise when travelling conditions are below average is given by the figures obtained by these investigators for extended transport and in years when decay was severe (Table I).

These figures, though representative of the worst conditions for intra-continental transit, still do not reflect a true image of losses entailed where long distances of sea travel are necessary or where extended delays occur between harvesting and retail sale. A three-week storage period for certain varieties of rot-susceptible oranges, for example, has caused 64% of the fruit to become unsaleable. Valencia oranges and grapefruit have become decayed to the extent of 20–30% of the total shipment and, until very recently, losses of 25% of stone fruit and imported pineapples were commonly accepted by buyers in north-eastern American markets. In Australia in 1950, 12% of oranges sold within that country were destroyed by green mould (*Penicillium digitatum*) alone. In the United Kingdom, where the climate is cooler and travelling distances are short, storage losses of this high order are not to be expected; nevertheless, the losses borne by the importer to this country will, in one way or another, be shared by the consumer.

Decays during transit are by no means the major proportion of losses of commercially grown fruit. Losses borne by the retailer and the housewife are generally even greater than those suffered by the farmer and wholesale merchant. Stokes [22] calculated that, in the United States, losses in retailing all fruit amount to 6·9% of the retail value, and Miller [18] noted retailers' losses of 20% for tomatoes and peppers, 15% for tangerines, 12% for raspberries, and 10% for strawberries in the shops of Knoxville, Tennessee. A survey of 200 housewives showed their losses to amount to 15% for strawberries, 10% for oranges, and 8% for raspberries. Thus, unless positive action is taken to protect fruit against the many fungal parasites that are capable of rendering it unsuitable for consumption, a high proportion of the original crop will be lost. As one example, 25% of oranges may be lost during transit, 11% when on sale and 6% after purchase by the housewife. In short, almost half the time, labour and land devoted to the cultivation of the fruit may be wasted.

TYPES OF SPOILAGE

Though many fungal parasites attack fruit indiscriminately the damage they do is often governed by the physical characteristics of the fruit, especially its softness and the degree of protection afforded by the skin; for example, a mould that can attack and permeate a soft-skinned fruit may be found on a thick-skinned sort only after this has suffered some form of skin damage. Nevertheless, certain moulds will attack their hosts in some specific manner which may influence the methods of control, and it is therefore convenient to classify fungal storage diseases according to the host fruit or its family. A series of booklets issued by the U.S. Department of Agriculture as aids to inspectors of the Food Products Inspection Service [21] describes with the aid of numerous colour plates the storage diseases of all common and several tropical fruits, with recommendations for minimizing the damage caused by the infections. The decays responsible for most of the losses in stored fruits are listed in Table II.

Citrus Fruit

The most frequent cause of decay in stored oranges are the blister rots and the stem-end rots. Blister rots are caused by species of penicillia invading the areas where the skin has been weakened by bruising or injured by birds or insects and may consist of a green sporulating surface growth of *Penicillium digitatum* or a blue growth of *P. expansum* or *P. italicum*. Stem-end rots begin as discolorations round the stem button and penetrate the flesh with such rapidity that complete decay may ensue within four days. Two fungi are responsible, *Diaporthe* (*Phomopsis*) *citri* which is particularly prevalent in Brazilian and Florida oranges, and *Botryodiplodia natalensis* which is found mostly on South African and West Indian fruit. Both species may occur in a single delivery of fruit, the dominance of one over the other being largely determined by temperature: *Phomopsis* grows best at 73° F., *Botryodiplodia* at 86° F.

Navel oranges are particularly susceptible to alternaria rot which attacks at the stylar end of the fruit, causing at first a blackening of the centre then later spreading throughout the flesh. Several other common decays of citrus fruit are associated with the penicillium rots. They include oospora rot which produces soft, slimy fruit, brown rot which develops from an orchard infection but spreads by contact, and a pink rot of lemons. This last differs from a somewhat similar pink rot, widespread on citrus and most other fruits and vegetables, caused by *Sclerotinia sclerotiorum*.

TABLE II

FUNGI CAUSING DECAYS OF FRUIT IN STORAGE

Species	Host	Decay
Alternaria brassicae microspora	Melon	Alternaria rot
A. citri	Citrus	Black rot, centre rot
Aspergillus carbonarius	Grape	Black mould rot
A. niger	Grape	Black mould rot
A. spp.	Citrus, banana	
Botryodiplodia natalensis	Lime	Charcoal rot
Botryodiplodia natalensis	Citrus, melon	Stem-end rot
B. theobromae	Banana	
Botrytis cinerea	Many fruits	Grey mould
Cephalosporium roseum	Melon	Pink mould
Cephalothecium roseum	Banana	
Cercospora spp.	Banana	
Cladosporium baccae	Grape	
C. cucumerinum	Melon	Cladosporium rot
Colletotrichum lagenarium	Melon	
Corticium centrifugum	Apple	Fisheye
Cytosporina sp.	Citrus	
Diaporthe citri	Citrus	Stem-end rot
D. perniciosa	Pome fruit	Black rot
Dothiorella sp.	Citrus	
Fusarium spp.	Banana	
F. oxysporum var. *aurantiacum*	Grape	
F. scirpi var. *compactum*	Melon	Stem-end rot
Gloeosporium spp.	Citrus	Anthracnose spot
Glomerella cingulata	Pome fruit	Bitter rot
Glomerella cingulata	Banana	Anthracnose
Monilia sitophila	Melon	
Mucor spp.	Many fruits	
Nematospora spp.	Citrus	Dry rot
Neofabraea spp.	Apple	Bull's-eye rot
Nigrospora spp.	Banana	Squirter disease
Oospora spp.	Citrus, banana	Oospora rot
Penicillium spp.	Most fruits	Green and blue mould
P. roseum	Lemon	Pink mould
Pestalotia leprogena	Banana	
Phoma spp.	Pome fruit, citrus	
Phomopsis spp.	Banana	
Physalospora cydoniae	Pome fruit	Black rot
Phytophthora spp.	Melon	Phytophthora rot
Phytophthora spp.	Citrus	Brown rot
Pleospora spp.	Citrus	
Pythium spp.	Melon	
Rhizoctonia bataticola	Melon	Charcoal rot
R. spp.	Citrus	
Rhizopus nigricans	Most fruits	Rhizopus rot
Sclerotinia cinerea	Stone fruit, apple	Brown rot
S. fructigena	Stone fruit, apple	Brown rot
S. sclerotiorum	Many fruits	Cottony (pink) rot
Sclerotium rolfsii	Melon	
Sphaeropsis malorum	Grape, apple	
Stachylidium theobromae	Banana	
Thielaviopsis paradoxa	Banana, pineapple	Black (soft) rot
Trichoderma lignorum	Lemon	Trichoderma rot
Tricothecium roseum	Apple	Pink mould
Vermicularia dematium	Banana	
Verticillium spp.	Banana	

Descriptions of these and minor rots are to be found in books by Fawcett [6] and Batchelor and Webber [5]. Coloured illustrations of the rots are shown in Klotz and Fawcett's *Colour Handbook of Citrus Diseases*, 1948.

Apples and Pears

Soft rots occurring in apples and pears during transit are said to be responsible for 15% loss in total output in New Zealand. In America, however, returns from market inspectors have shown losses of less than 3%. One major cause of storage losses is blue mould (*Penicillium expansum*), which has been responsible for more than 60% of all infections in deliveries to U.S. markets. Another important rot, caused by *Glomerella cingulata* (*Gloeosporium rufomaculans*, *Colletotrichum gloeosporioides*), starts from an orchard pathogen but spreads by contact until the whole of a crate disintegrates into a soft gelatinous mass. *Botrytis cinerea* produces a browning of the flesh but does not infect healthy fruit and is not therefore spread rapidly in stored fruit of good quality. The true brown rot, due to *Sclerotinia fructigena*, is able to attack fruit on the tree as well as in storage. Although the whole of the flesh becomes damaged (Figure 1) the rot is less widespread and devastating than a similar rot of stone fruit. Pink rot (*Cephalothecium roseum*) is reported to appear only on fruit damaged in the orchard by black spot (*Venturia inaequalis*). Fisheye rot (*Corticium centrifugum*), named from the appearance of the lesions, is found in apples only. Other rots are noted in Table II.

Stone Fruit and Soft Fruit

The most prevalent and wasteful of the decays attacking stone fruit is brown rot caused by infection with two species of *Sclerotinia*. Brown areas appear on the skin and the whole fruit can become discoloured and rotted within three to five days. Up to half the peaches reaching the markets have been rendered unsaleable by this disease alone. It is still common for whole cases of peaches and apricots to be so infected as to be rejected outright, and because infection occurs in the orchard care in handling or packaging will not control the disease satisfactorily.

Blue mould comes next in importance to brown rot as a storage disease of stone fruit. Unlike brown rot it arises only when the skin of the fruit has been previously damaged. Rhizopus rot also follows upon skin injury and eventually breaks down the tissues into a soft watery mass. The least important of the four rots of stone fruit is that due to *Botrytis cinerea*; like blue mould and rhizopus rot it attacks damaged fruit only.

Berry fruits with their thin cuticle and high juice content are particularly prone to attack by the ubiquitous *Penicillium*, *Rhizopus*, and *Botrytis* fruit moulds. Decay, once started, spreads rapidly from fruit to fruit, and losses during retailing and after purchase are high.

Bananas

Four types of fungal damage are to be found in bananas, but many different fungi may be responsible for them. They include rotting of the main stem; cushion rot which attacks the hand supports and which may spread to the finger stalks and fingers; finger stalk rot which results in dropping of the fingers, and finger diseases of the fruit itself [25].

Stalk rots may be caused by *Thielaviopsis paradoxa*, *Botryodiplodia theobromae*, *Glomerella cingulata* (*Gloeosporium musarum*), *Phomopsis* and *Fusarium* species in association with secondary invaders. "Finger dropping" may arise when any of the first three of these fungi spreads from the main stem to the cushions and finger stalks. Anthracnose, perhaps the most widespread disease, begins as dark spots which subsequently coalesce, later developing salmon-pink pustules of *Glomerella cingulata* (Figure 2). An even more severe decay, caused by *Botryodiplodia theobromae*, produces a spreading black discoloration which renders the fruit soft and pulpy. Infection with *Fusarium sambucindum* may give rise to a softening and pulping of the distal end of the finger. Squirter disease, caused by *Nigrospora musae* or *N. sphaerica*, is essentially an Australian plantation disease but may develop during transport and storage.

Grapes, Melons and Pineapple

Without some effective means of inhibiting fungal development, commercial importation of grapes from South Africa to the United Kingdom would not be practicable. As with other soft fruit the chief damage arising during storage is from species of *Penicillium*, *Rhizopus* and, especially, *Botrytis*. Other common diseases are a black mould rot caused by *Aspergillus* species and a woolly mould rot due to a *Fusarium*.

Rhizopus soft rot is the chief cause of deterioration in stored melons. The rind is first softened and the underlying tissue becomes soft and watery. A similar but even more severe tissue collapse can occur from bacterial soft rot, due to *Erwinia* species. Various stem-end rots are caused by different species of *Fusarium* and by *Botryodiplodia natalensis* which first appears as a grey mycelium, later developing black sclerotia. Finally, discoloured spots on the skin may later turn into spongy tissue rots from *Alternaria* and *Cladosporium* infections.

Black or soft rot due to *Thielaviopsis* (*Ceratocystis paradoxa*) is common on pineapples all over the world. In the majority of infections the fungus enters the cut stem of the fruit and rapidly produces tissue breakdown. It may also enter bruised fruit at the sides. Brown rots infected with *Penicillium*, *Fusarium* and other species are less common and are thought to arise only when skin damage has opened the flesh to saprophytic invasion.

METHODS OF PRESERVING FRESH FRUIT

Cold Storage

Perhaps the simplest and safest method of extending the storage life of fresh fruit is by refrigeration; it is also the one most commonly used and the oldest. Cold storage of fruit has now become a science in itself: temperature, relative humidity and composition of the atmosphere in which the fruit is stored are all highly critical and differ for each type and variety of fruit.

Grapes and pears may be stored in safety at freezing point, whereas some varieties of apple must not be cooled below 38° F. Gros Michel bananas suffer skin damage and do not ripen properly if held below 53° F. [24]. Citrus fruit and ripening pears develop skin burn if held at temperatures below their specific optima and tend to acquire a bitter taste. The flesh of Victoria plums turns brown if the plums are stored for a few weeks at 32° F. Melons, though not visibly affected by storage below 50° F., rot rapidly as soon as they are brought back to room temperatures.

One important aspect of correct storage temperature is its effect on flavour. This is exemplified in tasting trials on apples of the same variety stored at 30° F., 32° F. and in cool store: the flavour of those kept at 32° F. approached that of cool-stored fruit, but at 30° F. flavour was never very pronounced nor did the apples reach perfection on removal from store [19].

Humidity in the cold or cool store is just as important as temperature. If the atmosphere is too dry the fruit will slowly desiccate; if it is too moist mould growth will be encouraged. A relative humidity of 85–90% is satisfactory for most varieties of stored fruit.

The proportion of inert gas in the atmosphere of the store, and particularly the CO_2/O_2 ratio, is important in determining storage life. An increase in carbon dioxide reduces respiration rates of fruit, but an excess will damage the fruit by permitting accumulations of acetaldehyde. The method of controlled gas storage first developed by Kidd, West and Kidd [14] is now used extensively for both apples and pears. Optimum gas concentrations for Cox's Orange Pippins are 5% carbon dioxide and 2½% oxygen, and for Bramley's Seedlings 10% carbon dioxide and 11% oxygen.

Simple Coatings and Wraps

Plain or oiled individual paper wraps have proved very useful in preventing spread of mould from one fruit to the next. Skin coatings of wax or plastic material serve additionally to slow down metabolism of the fruit by increasing the carbon dioxide content. Pears coated with a wax emulsion and stored at 34° F. have kept in good condition for weeks longer than uncoated pears. There is, however, the danger of too efficient a coating leading to build-up of carbon dioxide with its attendant dangers of alcohol and aldehyde auto-intoxication. Thus, rubber hydrochloride coatings may restrict gas exchange so effectively as to cause browning and scald of apples coated with them.

Much experimental work has been done with different plastic coatings for hard and citrus fruits. Vinyl copolymers plasticized with dibutyl phthalate, copal resin, castor oil/shellac, and cellulose acetate have all been tried with some success, but paraffin wax emulsions alone have held their own as moderately useful aids to long-term storage of pome fruit and citrus. Storage life may be increased by 50% following wax emulsion dips, and most exported citrus varieties are now wax-coated. A typical formula comprises:

Microcrystalline paraffin wax ..	6%
Methacrylate resin	6%
Emulsifying agents	2–3%
Water	to 100%

Soft fruits keep better in plastic film wrappers than in wooden boxes, cellulose acetate films being the most suitable for strawberries and raspberries. Polythene liners in grape boxes have reduced decay from 41% of the pack to less than 4% [23]; polythene wraps are also claimed to be the best material for export of avocado pears, the more permeable paper and cellulose wraps permitting too rapid ripening. On the other hand, more decay has been found to arise when oranges are held in polythene bags than when they are in string mesh bags.

Fumigants

A well-established commercial fumigation treatment for citrus and melons is the Decco process which uses nitrogen trichloride as the fungicide. Both stem-end rots and attack by *Penicillium* are materially reduced by repeated fumigation for 4-hour periods at a vapour concentration of 6 mg./cu. ft. The treatment is not effective against skin-penetrating fungi unless it can be applied within 24 hours of infection.

One other popular gaseous fungicide, used chiefly on grapes, is sulphur dioxide. It is applied in the form of a 40% solution of sodium bisulphite sprayed over the wood wool in which the fruit is packed. The concentration of SO_2 released into the surrounding atmosphere should not exceed 15–20 p.p.m.; concentrations below 7 p.p.m. are without antifungal action [20].

A recent successful treatment for boxed citrus fruit, developed in the Riverside Laboratories of the University of California, is ammonia gas liberated at a controlled slow rate by careful choice of ammonium salt, this being impregnated into the paper crate linings [10]. Ammonium succinate has been found to give the best rate of release for the purpose, but mixtures of ammonium sulphate and a mild alkali have also been used with satisfactory results. More recently, the method has been employed to control rhizopus rot on peaches, but when tried on berry fruits it caused discoloration and tissue softening.

Other chemicals that have been proposed as vapour phase fungicides for packed fruits have included alkylene oxides, chlorinated ethanes and ethylenes for soft fruit, and 2 : 4 : 5-(trichlorophenoxythio)-trichloromethane for apples.

Chemical Washes and Dips

Inorganic boron compounds were among the first of the aqueous dips to be tried for preserving citrus fruit, and sodium borate is still one of the very few successful treatments in use today, particularly in Australia. At first [4, 7] cold borax dips were used to control attack by stem-end rots and blue and green moulds; later, in attempts to increase efficiency, the concentration of the solution was increased by using warm baths (borax being soluble to the extent of 8% at 110° F. but to only 2% at 60° F.), or a mixture of borax and boric acid was used. Finally, the more soluble sodium metaborate was substituted for borax and is still used in many packing stations at a 4½–5% concentration.

Borates operate most effectively against *Penicillium* moulds and have reduced wastage in Australian oranges by two-thirds [11]. On the other hand, there have been several examples of the stimulatory effect of borates on other rots of citrus, and in many packing houses they are now employed only in association with other preservatives. In Israel, Brogdex treatment (borax dip and waxing) followed by diphenyl wraps is considered to give the best protection against both *Penicillium* and stem-end rots [16].

While borates have proved outstandingly successful for citrus storage other inorganic fungicides have been of little or no value. Chlorine washes are still used for temporary disinfection before applying more lasting treatment, and copper salts have found limited use for protecting melon stems against rot and for impregnating paper wraps for control of grey mould in pears.

Numerous organic chemicals have been examined for the preservation of fruit, particularly citrus, and simple rapid screening tests for chemicals against *Diplodia*, *Phomopsis* and *Penicillium* have been in progress for a number of years at the two principal citrus research stations in the United States. Despite the examination of thousands of chemicals in these tests the best chemical dip treatment remains that discovered by Tomkins in 1936 (*Food Invest. Bd.*, 1937) and patented in a modified form in 1954 [13]. This consists of a solution of sodium *o*-phenyl phenate buffered with caustic soda or other alkali to a *p*H of 12·0 or, in place of alkali, with an organic base such as hexamethylene tetramine. Without the buffering action of the base the sodium *o*-phenyl phenate, though initially alkaline (*p*H 11·0), would become carbonated by atmospheric CO_2 to produce the free phenol which would burn the skin of the fruit severely. Even in the presence of alkali sodium *o*-phenyl phenate will damage the skin of some types of citrus fruit and in many packing houses it is the practice to wash the fruit after treatment, thereby ensuring a minimum retention. The extent of rind burn, which may not appear until after several weeks of storage, is roughly proportional to uptake of chemical, but depends too on the variety of fruit.

Sodium *o*-phenyl phenate will not protect citrus for more than two or three weeks and, like borax, is best used in association with other chemicals. Nevertheless, it has been stated that half of the annual citrus exports from California, at present worth $400 million, would be decayed on arrival at the selling points if no preservative treatment were given. By use of sodium *o*-phenyl phenate the loss is reduced to 1%, a figure that is regarded as still too high [9].

Sodium *o*-phenyl phenate has been found very variable in its effect on citrus. It protects Californian oranges less well than Florida oranges. It protects Florida fruit from stem-end rot but not South African fruit which is attacked by a different fungus. Protection against stem-end rot of lemons also may succeed or fail according to the variety of fruit and the species of invading organism.

The treatment favoured in the U.S.A. is that proposed by Hopkins and Loucks [13] and comprises an immersion for up to 2 minutes in a solution of 2% sodium *o*-phenyl phenate and 1% hexamine. In South Africa much more dilute solutions are used, generally 0·15% sodium *o*-phenyl phenate for 3 minutes. In Australia control of the dip bath is achieved by soda instead of hexamine and the fruit is washed after treatment.

Within the last two or three years the success of sodium *o*-phenyl phenate for citrus preservation has been greatly enhanced by combining the chemical with a growth regulator such as 2,4-D or 2,4,5-T. All stem-end rots enter the fruit after attack on the button and if this can be kept healthy

TABLE III

PERCENTAGE WASTAGE OF STORED CITRUS FRUIT AFTER DIPPING IN SODIUM *o*-PHENYL PHENATE/HEXAMINE WITH AND WITHOUT 2,4-D

(Data from Andrade *et al.* [2] and Loest *et al.* [17])

Type of fruit	Untreated	Without 2,4-D	With 2,4-D
Oranges			
Brazilian	8·3	2·8	0
Brazilian	10·7	8·0	7·7
S. African (navel) . .	4·2	2·7	1·6
S. African (Valencia) . .	0·9	0·6	0·2
Lemons			
Brazilian	54·4	50·9	19·9
Brazilian	23·5	21·4	7·9

during storage such rots will not gain a foothold. The growth regulators, typified by 2,4-D, maintain the button in a green, healthy state during storage and thus, in combination with sodium *o*-phenyl phenate, enable citrus fruit to be shipped and stored with negligible losses from decay. Table III gives examples of the effects of the combined treatment.

Since the introduction of sodium *o*-phenyl phenate into the citrus packing industry in 1950 most of the main exporting countries have depended almost exclusively on its use together with supplementary aids, such as 2,4-D or impregnated wraps or coatings.

Sodium *o*-phenyl phenate has not achieved so rapid a success for protection of other fruit, largely because of the greater risk of skin damage in thinner skinned fruits. A 0·5% dip will control fairly efficiently brown rot of peaches though it has little effect on the less common rhizopus rot. The widespread adoption of the chemical in the U.S.A., however, is indicated by recent legislation on residue tolerances: the maximum amounts permitted on fruit exposed for sale in the shops is 20 p.p.m. on peaches, 10 p.p.m. on oranges, other citrus fruit, pineapples and melon flesh (melons may have 125 p.p.m. on the whole fruit), and 5 p.p.m. on apples and pears.

A monochloro derivative of sodium *o*-phenyl phenate has been found to be the most effective compound for dip treatment of apples and pears and is now widely used in the United States. Blue mould and bull's-eye rot are controlled by it, and in extensive user trials decay was reduced to negligible proportions by aqueous dips. To avoid burning the fruit the *p*H must be kept above 8 and an adequate wax coating must follow the dip.

A few other chemicals have shown promise for specific applications in decay prevention. Salicylanilide has proved to be of value against squirter disease of bananas, used as a 0·17% dip or spray of the sodium salt; with an increase in concentration up to 0·6% control can be obtained of stem-end rot, pink rot and finger drop.

Organo-mercury compounds will give good control of many fruit diseases, but the health hazards are too great to permit their adoption in practice, although it is claimed that apples coated with an oil emulsion containing 0·035% phenyl mercury chloride retain only 2–3 p.p.m. of mercury in the skin and this disappears completely before the fruit is sold in the shops.

Other chemical treatments of experimental interest are thiourea (now discredited on grounds of mammalian toxicity), 2-amino-pyridine, pyrrolidine, and sorbic acid for berry fruit. Antibiotics have given some success but their cost is high.

Chemically treated Coatings and Wraps

During the first world war the importance of ensuring the good condition of shipments of citrus fruit from Palestine to Great Britain prompted intensive study into methods of extending storage life, the outcome of which was the diphenyl-impregnated paper wrap, still perhaps the most popular treatment for oranges and grapefruit. Diphenyl wraps control penicillium rots but not stem-end rots. Indeed, by their slightly toxic action on the buttons of wrapped oranges, they may even increase decay by *Alternaria*, *Diplodia* and *Phomopsis*. Diphenyl may be impregnated into wrapping papers or into the paper linings or inlays of citrus boxes. Diphenyl wraps now tend to be used additionally to aqueous dips and wax skin coatings, and thereby improve substantially the degree of protection achieved (Table IV).

Diphenyl may impart a barely noticeable taint to oranges and a somewhat more perceptible taint to grapefruit, but it is without appreciable mammalian toxicity and a concentration of 110 p.p.m. on the fruit is permitted in the United States. In Great Britain diphenyl-impregnated wraps must not contain more than 40 mg./100 sq. in.

As an alternative for the treatment of paper wraps French growers have experimented with quaternary ammonium compounds, such as cetyl trimethyl ammonium bromide. Papers saturated

TABLE IV

PERCENTAGE WASTAGE OF STORED CITRUS FRUIT AFTER DIPPING IN SODIUM *o*-PHENYL PHENATE/HEXAMINE AND WRAPPING IN DIPHENYL-IMPREGNATED PAPER

(Data from Andrade [1], Godfrey and Ryall [8] and Harding *et al.* [12])

Type of fruit	Untreated	Dipped only	Dipped and wrapped
Oranges			
Florida (Valencia) ..	7·3	2·2	1·2
Florida (after shipment)	21·6	7·0	2·4
Brazilian	44·0	37·0	38·0
Lemons			
Texas (Eureka) ..	50·6	25·0	11·3
Texas (Meyer)	32·8	9·9	3·6

with a 2% solution have reduced orange decay by approximately two-thirds. The same quaternary salt has been proposed for use in a gel of carboxymethylcellulose which may be applied to the fruit as a dip or a spray. Borates, salicylanilide, diphenyl and sodium *o*-phenyl phenate have all been used as citrus preservatives by incorporation into wax emulsions. The method generally reduces decay by some 50% only and is less effective than when chemical treatment and waxing are carried out as two processes, as is now the usual practice.

CONCLUSION

Much experimental work is still going on to find the ideal preservative for stored or exported fruit. No fully effective means has yet been developed, but the progress made has been enough to tip the scales from economic failure to commercial success for the majority of fruits in transit.

One major difficulty is that fruits differ in susceptibility not only to the many storage diseases but to the chemicals employed in their control. Certain types of rot which can be prevented by a chemical in one part of the world may even be encouraged by the same chemical in another part. The multiplicity of factors governing the control of disease, included among which are susceptibility of fruit to mould, species of mould attacking the fruit, phytotoxicity of the control chemical, pre-harvest conditions, and conditions and duration of storage, render the prospects of efficient control by a single chemical highly unlikely. The alternative of radiation sterilization is being studied but the subject is still in its infancy.

Nevertheless, in comparison with the progress made on the control of fruit diseases arising before harvesting, the victory over storage diseases has been almost complete and it is possible to foresee within a few years the disappearance of fungal decays from all fruit in the markets. The increased life thereby attained may bring other problems in its train, for even sound fruit stored for long periods will undergo ageing and flavour changes that may influence its acceptability to the consumer.

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REPRODUCTION PROBLEMS IN BRITISH CATTLE

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Bovine infertility is a major cause of trouble and loss to farmers in Britain and other lands. Under this term come a number of conditions leading to failure to breed, thereby shortening the working life of the average dairy cow. They comprise physiological derangements of different kinds as well as infection by bacteria and other organisms, and such factors as heredity, management and nutrition may all contribute to producing a problem.

Failure to breed, as an important husbandry hazard, made its appearance in history not long before the middle of the nineteenth century. At this time it received most notice in states such as Switzerland, Denmark and the Netherlands where the thriving economy in a limited cultivable territory was chiefly dependent on an efficient and balanced agriculture, but in Great Britain where a dense population had long been supported by the export of manufactures, and most of the land was in the hands of a relatively small number of large occupiers, little interest was taken in the subject. Just before the 1939–45 war only three whole-time veterinary experts were employed in this sphere. Naturally, war conditions brought about a great change, and by 1944 at least a dozen more were at work, including the present writer. The extension of artificial insemination from that time onwards served to spotlight infertility and so to provide additional occupation for the staffs concerned, a factor which applied also to the United States and to the more advanced European countries. Since 1955 a marked increase in both British and World interest can be recorded. The third International Congress on Animal Reproduction, held at Cambridge in 1956, was far better attended (by over 400 specialists) and reported than its predecessors; and the doubled volume of published research in that year, as compared with the post-war average, was exceeded in 1957 and again, considerably, in 1958.

HERD INFERTILITY PROBLEMS

It is found in practice that whereas the mildest manner in which bovine infertility can hit a farmer is the temporary affection of one or two individual cows, most alarm is occasioned by a similar outbreak affecting a substantial proportion of the herd, sometimes leaving one or more permanently sterile animals in its wake. In addition the steady drain caused by the occurrence of such occasional barrener discards in normally breeding herds has to be considered. Each of these three types of loss has to be measured by a different technique, and only in the case of the last can any approach to an accurate estimate of the incidence be formed. Some information on the importance of the temporary case is provided by a 1954–5 survey [13] on the proportions of different disease types to which veterinary surgeons were called, in a series of representative dairy practices. Infertility "non-specific and functional" was the commonest condition of all, with over 20 cases per thousand head per annum.

Various definitions have been used to indicate what constitutes a "problem herd." Hignett in 1950 [18] proposed that herds with one-third of the breeding stock failing to conceive to three services, or comparably infertile otherwise, should so qualify. The Milk Marketing Board prefer the failure of over half the herd to conceive to the first service, a slightly less serious impairment, but a less precise definition, since if most of these cattle conceive to the second service all is well. This imprecision is reflected in a report by Smith [36] in 1958 that 14% of a cross-section from 1400 herds in three M.M.B. regions had herd problems by this definition, whereas the same worker [37] in 1955 reported a hard core of "economic" problems requiring professional assistance in only 4% of 5000 East Anglian herds. There does appear also to be a regional variation in the incidence of such problems, for in Devon Wilson [41] could find only 30 such out of 4000 herds (based on Hignett's definition), or 0·75%. This incidence was confirmed in 1957 for the same area by Boyd [5]. Smith and Munro [37] suggested that husbandry differences, such as the extension of winter milk production and feeding with imbalanced by-products in East Anglia, could account for this variation. Were this correct, it would suggest an intermediate incidence in the interlying areas;

should it be permissible thus to "split the difference" a country-wide mean of 2½% problem herds can be postulated.

Milk Recorded herds in Britain contain 29% of the cow population and have a mean size of 34 head. Taking this to represent roughly the national average herd size, as there are about 78,000 herds in the country, about 2000 economic herd problems may occur annually involving at least 23,000 cows, calculated at one-third of each herd. There appear now to be something like the equivalent of 48 veterinarians engaged whole-time on this work, suggesting that every problem could receive attention if each worker dealt with just over 40 each year. The real number of herd problems is likely to be rather greater, and as some of them will not be seen by the specialist it seems that only a small majority of those that arise receive proper attention.

PERMANENT INFERTILITY

Table 1 summarizes the more important survey findings bearing on the extent of loss. The British data with the exception of those by Withers [42, 43] are representative of the cow population as a whole; thus Stewart and O'Connor's [38] figures are from 11,000 herds containing 200,000 head selected at random throughout England and Wales. Withers's survey was based on results from four southern English counties, where possibly husbandry was more intensive and progressive than the average. The American figures [28] are those for a single large Friesian herd. The different authorities agree remarkably closely on the extent of the total annual cull, and vary only from 12·5 to 20% in their estimates of the proportion for which permanent infertility is responsible, with an average of 15·7%. Little change over the years was apparent. Withers's results agreed quite well with those from the National Investigation into the Economics of Dairy Husbandry [2] that infertility was almost as important a cause of discard as all other diseases together.

Smith [36] has recently put forward the proposition that such percentages as these for infertility discard may grossly exaggerate the importance of the condition, for he considers that many cows not conceiving to only one or two services may thereupon be sold owing to the high prices prevailing for beef; but at least three of the five sources for Table I provide sufficient detail largely to refute this contention as far as their own results are concerned. Withers's requirement was for an "infertility discard" cow to have been served three times in vain, or to have been affected comparably long with genital disease precluding service. These criteria would not completely rule out consideration of an animal's beef value in deciding about her disposal; but Stewart and O'Connor explicitly state that their figures refer to "true" infertility, and tabulate elsewhere in their report the proportion of "barreners not necessarily truly infertile," while Morrison and Erb [28], too, make the point that infertility was the *sole* cause for disposal in arriving at their 18% figure. Dawson [7] collected 252 cows of the main dairy breeds "discarded for failure to breed" from 97 farms, and investigated each case more fully. The commonest number of times for a cow to be served was six; 105 cows

TABLE I

INFERTILITY AS A CAUSE OF DISCARD FROM HERDS

Source	Period covered	Total annual cull %	Infertility cull (% of annual cull)	Remarks
Laing [24]	1948	25	16	—
National Investigation [2]	1951–2	29	—	49% of all disposals from "death and disease" were for infertility.
Withers [42]	1950–2	24	20	"All other diseases" accounted for 28% of the total cull.
Withers [43]	1952–4	22·5	15 and 12·6	Apparent fall in infertility coincides with intensive tuberculosis eradication, reactors disposal now 12%, Withers [42], 4%.
Stewart and O'Connor [38] ..	1955–6	24	12·5	—
Morrison and Erb [28]	1925–55	26	18	American data.

were served six times or more, and 43 four or five times, while only 16 or about 6% were expeditiously served from one to three times and then discarded, without having shown long periods of frank genital disease, or "temporary" pregnancy.

Hence it seems possible to accept an annual cull from all causes of about 25%, representing some 725,000 British cattle of which some 15% or 109,000 are discarded mainly or entirely on account of failure to breed; loss from this source is clearly many times greater than that due to herd infertility outbreaks, which involve a mere loss of time for 20–40,000 cows, but the psychological impact of which on the owner is so much more shattering that these outbreaks have come to absorb most of the time and energy of the specialist task force available to deal with infertility as a whole.

Permanent infertility is then probably one of the more important single causes in keeping the working life of our average cow down to about 4 years, whereas in Sweden and elsewhere 7 years is achieved. Lagerlof [23] has claimed that a long working life is of top economic importance in cattle. This bald statement can be expanded by pointing out the vital importance to livestock improvement of the ability rigorously to select replacement heifers, on the basis not only of yield but of longevity, feed conversion rate and ability to resist disease. Yet, with a short working life, most heifers have to be retained and the practice of buying them in is by no means uncommon.

INFERTILITY RESULTING FROM PHYSIOLOGICAL DERANGEMENT

Non-infectious infertility may be classified by cause or by the type and extent of the deviation from normal function. Classification by cause seems basically the more logical method but has the disadvantage of complexity. Heredity, management, specific details of nutrition (and even microbial infection) may all contribute to producing a particular problem. Further, the imperfection of our knowledge about the influence of each factor, with the great width of the field, favour classification by the second method, which may have the further advantage of presenting to the worker in other fields a clearer picture of the range of case encountered.

A preliminary sketch of reproduction in the dairy cow may be useful—84% of British cows are dairy cows and infertility of this type in the purely beef breeds is rare. About a month after calving the ovaries become active and produce a single follicle (about 1·5 cm. in diameter), which ruptures, shedding an ovum, and gives rise to a 2·5 cm., solid corpus luteum; this process continues at intervals of 18–25 days until service or insemination. Active external signs of heat are shown for up to 24 hours, during which period the cow will stand, but the ovum is not liberated from the ripe follicle until about 12 hours after the cow has ceased to stand or 33 hours after the first heat signs are noticed. As the ovum can survive only a few hours unfertilized, the period during which service can be effective is short. The corpus luteum takes about eight days to assume its solid form and full size and remains unchanged through the first half of a pregnancy period of 270–290 days, after which it slowly wanes. The fertilized egg arrives in the uterus on the fifth day and implants its membranes to form a placenta between the 30th and 35th days.

Suboestrus and Errors of Timing

Failure to breed occurs, despite normality of both partners, when the time of hand service or insemination does not coincide closely enough with shedding of the ovum; this is quite apart from the fact that bull fertility is known to be well below peak in the absence of the prolonged and increasing excitation that occurs in nature. Other aggravating factors are the tendency for a reduced duration and intensity of heat signs in intensively managed dairy cows, which makes it difficult for the herdsman to select the appropriate moment for service, especially in large herds where the animals may not always be watched with that careful interest so characteristic of the best type of small "family" undertaking. Work in America, Germany and South Africa has shown that in the cow, adequate gradual genital excitation assists sperm ascent and ovulation. Heinemann [15] has suggested that a succession of young vasectomized bulls should be run out with cows on which insemination or strict hand service has to be practised.

The tendency to poor heat manifestations frequently goes far enough to result in the abnormality of "silent heats" or suboestrus, in which there is little or no external sign of heat although ovulation and the cyclic formation of corpora lutea proceed normally and conception will occur to a well-timed service. Again, a bull run out will detect a proportion of these cases imperceptible to human senses; veterinary treatment comprises in the first line manual expression of the ripe corpus luteum, which is 50–60% efficient in producing an obvious heat in 3–7 days.

During the last ten years Hignett [19] in England, supported from Ireland by O'Moore [32] and other workers abroad, has convincingly confirmed earlier work suggesting the important influence on the ability of cattle to breed of the absolute phosphate content in the ration fed and also the calcium/phosphate ratio, and the probable interrelationship with the phosphate requirements of a need for manganese. Experimentally it was found that reducing phosphate intake to borderline or insufficient levels could produce silent heat and evoke some of the external signs of heat at the wrong time, i.e., in the presence of a ripe corpus luteum. Undoubtedly the same sequence of events occurs in some field infertility outbreaks.

Abortion and Foetal Resorption

Fertilization and the earliest stages of pregnancy successfully undergone, abattoir researches have shown that, apart from abortion of non-infectious origin, the internal resorption of a conceptus occurs quite frequently, with nothing to reveal the result beyond an unexpected return on heat. There is evidence that between 120–180 days the incidence of these occurrences is much reduced, one study on 690 cows giving total embryonic loss, of pregnancies established by clinical diagnosis, as 6·4% (mean of 5 years) with 0·58% occurring before 60 days, 2·46% for both the periods 60–120 and 180–240 days, and thus 0·9% for 120–180 days. So probably an artificial distinction can be drawn between "foetal death and resorption" up to 120 days and "non-infectious abortion" more common after 240 days. In producing the latter, genetic causes can sometimes be incriminated, as is instanced by the notorious "bulldog calf" in the Dexter breed and the comparable anasarcous calf in Ayrshires, in which breed also there is genetically controlled, prolonged gestation with similar unfortunate results. Occasional outbreaks due to ergot in pastures and a high seasonal and specific oestrogen content in the herbage have been authenticated; probably more common causes of late abortion and stillbirth are those associated with management. McDonald [26] has demonstrated an association with progesterone deficiency which seems also to be connected with a high breed metabolic rate; conversely, the low metabolic rate linked sometimes with iodine deficiency can be responsible [1].

Early foetal death, despite the above figures, may be important before even the 20th day of pregnancy [12]; a number of studies have gone far to establish that returns to service between 25 and 36 days imply its occurrence. On this basis Erb and Holtz [10] found on 2607 American cows over 30 years that the overall foetal death rate was 20·6% (confirmed by two other teams) and that while in heifers the figure was 26% it fell progressively till at the 4th–5th pregnancy it was only 10%; the proportions were similar in the more recent years after the elimination of recognized genital infection, indicating management factors in causation. The cow's permanent dentition is not complete until the age of about four years and (in Friesians) body growth continues until fully five years old at which age the cow if all has gone well has already borne her third calf. It might be thought that the nutritional demands of simultaneous reproduction and lactation under average feeding standards were equivalent to a 10% loss rate, while the added demand for skeletal growth on similar (or, for heifers, inferior) feed would account for the increased loss at the younger ages. British work has indicated that the average first calving age of heifers failing to breed after calving once only was 25 months, whereas that of animals surviving to complete five lactations was as high as 33 months.

As early as 1945 a school of workers in California claimed to have discovered a specific genetic cause for "zygote abortion," as it was termed, in many strains of Jerseys, but there has been no confirmation from the European breed. Recently, however, British evidence [31] has come forward that the parental inter-reactions of the six phenotypes of serum proteins may play an important part in causing early foetal death in most breeds—optimum fertility might only be expected if bull and cow are exactly alike in this respect. Work is now in progress to investigate this genetic aspect by trial of large-scale selective mating, which should of course serve as a control method if the theory is confirmed. Whereas early foetal death may also be a common effect of inadequate mineral nutrition, e.g. calcium/phosphate imbalance and manganese or perhaps copper deficiency, another important factor is involved in the tendency to serve cows too soon (45–70 days) after the last calving. There is abundant evidence that a peak conception rate is never reached before the 67th day and most studies delay the peak to the 90th–100th day. Presumably the attainment of peak lactation rate and so nutritional requirement, usually about the 36th day, is not unrelated to the variation in conception rate.

Ovarian Dysfunction

Derangement of the ovulating and luteinizing functions of the ovary must also be considered, notably delay in ovulation and inadequate production and maintenance of luteal tissue.

Rupture of the ripe follicle does not have to be delayed more than about 6 hours beyond the normal time to interfere with fertility; but in practice it is seldom possible to be certain that there is *delayed ovulation* for a less interval than 24 hours, so that the true quantitative significance of the condition remains unknown. A further hazard to accurate diagnosis lies in the readiness of the ripe follicle to rupture as a result of light manual contact; an accurate indirect method to detect ovulation in the cow, such as the paper technique recently evolved in gynaecological practice, is still awaited. Nevertheless the literature contains accounts of some striking outbreaks involving ovulation delay of up to 4 or 5 days in a number of British cases [17], and averaging 48 hours in 20% of a large mixed Friesian and native herd in South Africa [40]. Subsequent ovulation and luteinization appear to be normal; "delayed insemination" at 24-hour intervals until rupture of the follicle has proved a reasonably satisfactory control method. The immediate occasion must be inadequate production of luteinizing hormone by the anterior pituitary gland.

Inadequate luteinization appears to be a commoner condition, but this may simply be because it is easier to detect. The corpus luteum may be slow to develop and is small in size—frequently 1·5–2 cm. in diameter and thus half or less the mass of a normal body. Theoretically this deficiency could be due to shortage or diversion of luteotrophic pituitary hormone which has been proved in rats to control luteal development as well as to maintain milk secretion. Less easy to explain is the early regression in some of these inadequate corpora which have been shown to have a life span sometimes of only 4–8 days instead of the normal 14–16. Both Hignett and Ford have been able to link this abnormality with a specific mineral imbalance, excess of calcium to phosphate, while other British [6] and American [16] work has shown that exogenous progesterone (the secretion of the luteal cells) is helpful in overcoming the infertility. A significant incidence of 2–17 days between heat intervals, of up to 5%, has been reported, the proportion of these that may be due to this form of luteal inadequacy remaining as yet unknown.

When the pituitary secretion of gonadotrophic hormones is still further disturbed, not only may the supply of luteinizing hormone be inadequate but a gross excess of follicle-stimulating hormone may be produced. Instead of a single normal 1·5 cm. follicle a number may accordingly develop and, failing to ovulate, may continue to grow over a long period occasionally achieving a diameter of 7 cm. although about 3 cm. is more usual in this disorder—the notorious *cystic ovarian disease*. As the oestrogenic hormones responsible for the appearance of heat signs are secreted in the walls of the follicle, there is here a continuous high output of them into the circulation and in such typical cases nymphomaniac behaviour is conspicuous, though in successive "generations" of cysts the secretory tissue tends to degenerate, so that the oestrogen content of some may be quite low. In a minority of cows a defence mechanism working via the adrenal bodies is only partially successful in luteinizing the cysts, and in such cases androgens (chemically very similar to the luteal secretion) presumably are produced, for the subjects show a true virilism in their completely bull-like behaviour. In a further minority, perhaps one-third [8], the pituitary's production of luteinizing hormone remains unaffected, since normal (as well as some hollow) corpora lutea are produced at three-weekly intervals, and heat signs are intensified with similar regularity. Alongside this normal function the excess production of follicle-stimulating hormone continues chronically with a moderate permanent appearance of heat-like signs; in the mildest cases ability to breed may not be lost in this condition of "cyclic nymphomania," but more serious cases are common in which it is lost as thoroughly as in the simple type of disease—for instance, the constant high oestrogen level predisposes to secondary infection in the lower parts of the genital tract.

There seems every reason to suppose that the pituitary abnormality forms the primary lesion; from other animals there is some direct evidence that the function of this gland can be affected by nutritional deficiency, and such a view fits the facts applying to the cow. Significant variation between sire-daughter groups in feed conversion ability has been demonstrated [20]. Hereditary transmission of the cystic tendency has been proved for a number of European breeds, including the Friesian in Sweden, and the disease is clearly linked with high yielding capacity in all these breeds and in the Guernsey in Britain, for which breed also there is some evidence for hereditary transmission through either parent. The disease in fact seems to be the result of the high yielding capacity in those cattle with poorer feed-conversion ability, especially when feeding is suboptimal. Thus the incidence fluctuates with seasonal influences and fashions in husbandry such as manuring of pastures. Over the four years 1953–6 the overall incidence of this condition in a sample of English barrener discards was 25%, but it rose each year and a comparable rise in 1945–55 has been reported from New York State; a similar incidence in discards of 29% has been reported in Germany [4]. Obviously a long-term change in breeding policy might well lead to eradication; quite effective short-term treatment comprises repeated manual rupture of the cysts, and exogenous luteinizing hormone and progesterone therapy; it is not known how effective hormone treatment can be when rupture has failed.

The furthest departure from normal ovarian function occurs when follicles are not ripened but undergo early regression, or are not produced at all. In these circumstances a condition of *true anoestrus* is present with complete absence of heat signs. This seems to be a characteristic of absolute phosphate deficiency [19, 32] which is often linked with inadequate protein metabolism. In Sweden one breed showed an hereditary form, *gonadal hypoplasia*, affecting one or both of the ovaries which remained pea-like. As it was associated with good yielding potential there was a danger that the breed might become saturated with this defect; it proved possible, however, to institute drastic breeding control measures, so that the condition is now rare. A similar condition has been believed to occur in some British breeds but confirmation is still awaited. During the war, particularly, true "management" anoestrus was often seen in underfed heifers which it was desired to serve at the normal age. As an emergency measure treatment with follicle stimulating hormone may have been justifiable; it proved about 60% effective.

The classification adopted has given no opportunity to mention the interesting idea that a specific essential aminoacid deficiency may play a part in functional infertility. Several reports suggest that methionine in particular may tend to be lacking; there may be a connection with a reduction of plant species sown in pastures. Many interesting and important problems await solution on the connection between mineral nutrition and reproductive function, especially with regard to the inter-relationships of trace elements, calcium and phosphorus. In view of the proven association between high yield and cystic ovarian disease, and much other suggestive evidence, it does seem necessary always to consider non-infectious infertility against a background of the cow's performance in relation to the standards of husbandry. Thus Table II indicates that a major proportion of herd problems investigated is not associated with a recognized infectious cause, in an environment where husbandry conditions are in the course of a revolution. In two of these areas the percentage of non-infectious problems appeared to rise from 60 and 64 in 1954 to 87 and 90 in 1956.

TABLE II

PROPORTION OF HERD PROBLEMS NOT ASSOCIATED WITH INFECTIOUS CAUSES, 1954–6

(Vet. Invest. Serv., M.A.F.F.)

Area	No. of herd problems investigated	% free of recognized infection
Norfolk, Suffolk	220	74
Nottinghamshire, Derbyshire	150	65
Devon, Somerset	193	83
Bedfordshire, Northamptonshire, Cambridgeshire, Essex	78	74

INFERTILITY ASSOCIATED WITH INFECTION

Brucellosis and Vibriosis

The main pathogens known to account for by far the greater part of the 30–40% of infection-caused herd outbreaks are *Brucella abortus* and *Vibrio foetus*. Although *Brucella* has long been recognized as a cause of late abortion transmitted mainly by ingestion, only its successful control since 1942 by blood agglutination testing and vaccination has made it possible to detect in the course of the last four years another important form of the disease. There appears [22] to be some form of barrier in the empty genital tract which excludes thence blood-circulating antibody. This makes possible the existence of an "independent" venereally-spread disease form, which occurs certainly in Holland, Ireland and in the east and west of England [29, 39]. Blood antibodies tend not to exceed "doubtful" titre levels but the test for vaginal mucus antibodies, developed by Kerr, offers an efficient method of diagnosis and possibly of control, in connection with intra-cervical vaccination [39]. A sperm agglutination test is available for diagnosis in the male. One field worker [29] found this type of brucellosis to account for 18% of the total problems attributed by him to specific infection; in only 6 out of 19 affected herds had more than two abortions, each, occurred. The incidence of classical brucellosis as estimated from recovery of the organism from aborted foetuses has altered little during the last six years; the disease appears to be rare in Southern England and to become steadily commoner as scrutiny extends northwards.

The existence of vibriosis began to be revealed about 1949 as classical brucellosis came under control. Again there appears to be some form of genital tract barrier, and it is a specific venereal disease accurately diagnosable by the vaginal mucus test. Following an outbreak a good level of natural immunity often develops in the cows and control is based on this circumstance, together with treatment using streptomycin which may be either local or systemic and is particularly satisfactory in the male. Interpretation of the herd mucus test is complicated, for only about half the infected females show a detectable positive reaction of which the duration may individually vary from three weeks to four years, and one rare relative of *Vibrio foetus* produces similar test reactions, but only in isolated individual animals.

Although vibriosis perhaps more characteristically results in returns to service and early foetal death than in frank abortion, and although the organism is short-lived in foetuses, culture results from these do seem to justify a conclusion that the disease distribution varies regionally, occurring now most frequently in the Midlands, showing a steady incidence in most of the South, and being rare in the West, and Scotland. It is by a long way the commonest single cause of infectious infertility, accounting for an average of 65–75% of these problems, and from 17–40% of problems as a whole, according to reports from different areas and in different years. But the incidence is falling: official investigators diagnosed the disease in 40% of problems in 1955 but only 30% in 1956, and the percentage of recoveries made from foetuses dropped steadily from 5·3 in 1953–4 to 2·6 in 1957–8. Credit for this reduction can probably be assigned as much to the extension and decentralization of laboratory diagnostic facilities as to antibiotic treatment, including that of semen (which is usefully but not completely effective).

The suggestion has already been made that infections and other causes may act synergistically to produce a reproductive failure. Such a concept applies both to brucellosis and to vibriosis, possibly more to the latter than the former. One survey [30] showed over 30% of herds as yielding some positive mucus samples for vibriosis, whereas under 1% were vibriosis problem herds in the area during the year. In the same survey brucellosis reactor herds included 19·6% of the whole cow population, indicating that many animals can harbour either organism for long periods without showing injurious effects. The principle is generally admitted that a debilitated subject is less apt to develop a satisfactory immunity to infection, artificial or natural; thus with cows the husbandry standards may well be relevant in determining whether the presence of infection causes loss.

Response to antibiotic treatment for diagnosed vibriosis in cows is often poor when symptoms of functional trouble are also present, and in one such extensive outbreak [14] a continental worker obtained evidence linking with imperfect nutrition. Practising veterinarians often consider that in certain herds Brucellar vaccine immunity lasts for two years or less, whereas it is well established [25] that under husbandry conditions approaching optimum its duration is fully five years.

Minor Infections

Trichomoniasis, a disease caused by a protozoan parasite and very similar to vibriosis in its epidemiology, is all but extinct in Britain, but in central Europe and parts of America *Trichomonas* infection is still an economic problem. First recognized about 1929 [34] and in Britain in 1937 [11], the intensified wartime research showed it to be widespread. Some of the early artificial insemination centres were set up specifically to combat the disease and this policy had an immediate success, coupled with the vaginal mucus agglutination testing technique which was developed originally [33] in connection with this disease and later applied to vibriosis and brucellosis with far-reaching results. By 1949 the disease had become rare.

Since 1955 leptospirosis has shown up as a common cause of infectious abortion and infertility, not only in America but as close to us as Denmark; careful watch has not yet revealed its presence in British cattle. On the other hand there has been a small but steady annual recovery from British calf foetuses of such organisms as *Listeria*, *Pseudomonas*, *Salmonella*, haemolytic *Escherischia* and *Staphylococcus*, all of which have been incriminated as causing spectacular infertility on occasion abroad. The possibility exists then that they may play a not insignificant part in our own problems.

More important seem to be the effects of fungi and possibly of viruses. The existence of mycotic abortion, usually due to *Aspergillus* spp., has recently been well established [2], sometimes occurring in outbreaks; the incidence of fungi in foetuses approaches that of *Vibrio* (which does not survive well). There is world agreement on the occurrence of venereal infertility, not associated with bacteria or protozoa, and in connection with which various viruses have been described. On clinical and negative laboratory evidence such outbreaks seem to be not uncommon in England [27]. Contagious venereal vaginitis or "bullburn" is commoner still; more usually it is not associated with infertility, but at times such an association can be very marked [21]. With this disease a virus has been consistently recovered and shown to fulfil Koch's postulates.

The diphtheroid *Corynebacterium pyogenes* is often found in bovine semen and in uterine and tubal pus and aborted foetuses, and even more commonly on the mucous membranes of healthy cattle and other animals. There is clear evidence that this organism produces a definite toxin, but from all observed facts the conclusion must be against its possessing primary pathogenic qualities. It may follow a primary pathogen to produce genital abscesses and mucosal sclerosis, or its disease-producing properties may be called out by and complicate functional disturbance, such as stasis in *any phase* of the oestrous cycle. Mechanical injury to any part is also a sufficient stimulus, so that a delay in cycle resumption following a difficult calving offers an ideal opportunity. There is evidence that such low-grade ascending infection is responsible for the severe sclerosis of the oviducts which affected 52% of infertile females in British [9] and Egyptian [35] surveys. Such facultative pathogens may be expected still to present a problem when the primary infectious agents of infertility have come under full control, as well they may in the not-distant future.

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BOOK REVIEWS

The Fabric of Farming. A. N. Duckham. Pp. 224, with line and half-tone illustrations. Chatto and Windus, London. 1958. 15s. net.

This book, designed mainly for first-year students, is an attempt to explain the principles on which our farming system is constructed. As such, it breaks away from the usual pattern which is all too often a dull catalogue of the crops and livestock found in this country. The book attempts something more—namely to place British farming in the context of world agriculture and of history. As will be appreciated, this is a formidable task. The author is, however, unusually well qualified for the part, having been successively in charge of strategic planning in the Ministry of Food, then agricultural attaché in Washington, and finally Professor of Agriculture at Reading.

The method used is to trace the succession from extensive to intensive farming that recurs throughout the world. It can be traced from the cattle ranches of the western United States through wheat farming to the corn and hog farms of the Middle West. It can be traced from the sheep runs of the Welsh mountains to the mixed arable farms of the English plains. It can also be traced in history from the primitive food gatherers to the advent of the Norfolk four-course rotation in the eighteenth century. It is indeed obvious that the author regards intensive mixed farming as practised in England as a climax towards which other countries might strive in so far as their climate permits.

Can this thesis be accepted? Allowing for the simplifications inevitable in a short book, the answer is mainly yes. There might perhaps have been rather less emphasis on biological processes that are still by no means clear even to the agricultural scientist, and a little more on the cultural and economic factors that are equally important. The reader should be reminded that the principles enunciated apply to the production of an Anglo-Saxon diet in a temperate climate and not all of them can be applied elsewhere. A Chinese peasant could not afford the acres necessary to provide our diet. A Latin people might prefer wine and olive oil to milk and butter fat. In the tropics, plantation crops may be much more intensive than alternate husbandry. There is, moreover, not much mention of price or consumer preferences. Barley would grow well in fen soil, but the farmer will prefer potatoes or celery because the price is higher.

It is, of course, unreasonable to expect the author to cover the whole of this field in a book of this size. Many of the points mentioned will, no doubt, be dealt with in the succeeding volumes that are promised. In the meantime, this book is a welcome addition to reading lists and will certainly help students and others to take a less parochial view of British farming.

F. G. STURROCK

Agriculture and Animal Husbandry in India. M. S. Randhawa. Pp. xvi+364, with line and half-tone illustrations. Indian Council of Agricultural Research, New Delhi. 1958. Rs. 15.00 net.

There has been a vacancy for a comprehensive account of Indian agriculture ever since N. G. Mukerji's book, which served an earlier generation so well, became out of date. A favourable reception is therefore likely to be given to a volume under the authoritative authorship of Dr. Randhawa, Vice-president of the Indian Council of Agricultural Research, assisted by numerous Indian experts.

This is far from being an ordinary college textbook of agriculture. Much greater space is devoted to the geological and climatic background than is usual in such, and a chapter on fishes includes the marine forms. The chapters on individual crops do not, except for some minor crops, give directions for cultivation but rather concentrate on distribution—which is illustrated by numerous maps—with some treatment of adaptation of varieties to local conditions. Again, the chapter on irrigation gives details of many important Indian schemes but does not deal with the principles of applying water to crops and soil. The emphasis in fact is on India as an environment for crops and livestock rather than on the methods of producing these commodities. This is a legitimate and useful aim, but may disappoint some readers who from the title expect a book on Indian *farming*; they will look in vain for sections on such subjects as, for example, soil conservation or pasture management.

Some criticism may well be made of the proportion of space allotted to different subjects. Seven pages on rice and thirteen on cattle are quite unworthy of a country which has almost a third of the world's rice acreage and over a quarter of its cattle. By contrast, some crops of quite minor importance receive an undue allowance of space. Some recent technical developments in Indian agriculture are not mentioned, for example the manufacture of non-wither tea and the important research on hydroponics—in fact, vegetables are not included though there is a substantial chapter on fruit.

The book is well produced, though $11\frac{1}{2} \times 8\frac{1}{2}$ in. is too large a size to be handy. There are too many misprints, and some uncertainty in the use of the English definite and indefinite article. The illustrations are clear and well printed, but some of them are only photographs of common crops in growth. A number of statistical tables at the end provide some useful figures on Indian agriculture, though one on "Substitutable Crops" is not adequately explained.

In short, Dr. Randhawa's book will be appreciated for the large amount of information it contains, though some readers will regret that it did not contain more or of a different kind. G. B. MASEFIELD

Land: The 1958 Yearbook of Agriculture. Edited by A. Stefferud. Pp. xv+605, with half-tone illustrations. The United States Department of Agriculture, Washington, D.C. 1958. $2.25 net.

When the 1938 Yearbook of Agriculture *Soils and Men* was published, Part 1 of the book was titled *The Nation and the Soil* and dealt largely with the economic and sociological aspects of land usage. Problems of tenancy, finance, legislation for public and private lands, etc., were thus dealt with first; the subsequent four parts were concerned with the physical aspects, i.e. with the soil itself. In the preface to the 1957 Yearbook *Soil* the editor pointed out that, because of the rapid expansion of knowledge of the soil in the preceding twenty years, it was necessary to confine that volume to a consideration of soil management and that a subsequent Yearbook would be devoted entirely to questions of the use and ownership of land. Such is the 1958 Yearbook *Land.*

This is essentially a book about America. The principles of soil science, plant pathology, entomology, etc., are the same all over the world; the principles behind land usage (if such things really do exist) are dependent on the physical environment, on the social and racial background of the people who settle on it, and on history. The introduction is a magnificent series of pictures illustrating the history of land use in the U.S.A. from the landing of the Pilgrim Fathers to the present day. A second series of illustrations consists of photographs demonstrating the appearance of various crops, forests, terracing and other land features from the air.

As two of the contributors to this volume point out, "land is many things to many persons—to the farmer, livelihood; to the townsman, space or a place to build his house; to the child, a playground; to the poet, a theme; to the patriot, a symbol." By and large, in this book the term "land" is used in the economic sense, meaning the "entire natural environment—all the forces or opportunities that exist independently of man's activity," i.e. the soil, slope, rainfall, water, mineral deposits and so on. Naturally agriculture and forestry receive most attention.

The story of the gradual acquisition of the areas which now constitute the U.S.A. makes fascinating reading and shows some remarkable bargains—for example, the purchase of Alaska from Russia in 1867 (which completed the acquisition of public lands for the U.S.) for two cents an acre. The names "Seward's Icebox," "Walrussia" and "Icebergia" indicate that at the time many Americans believed that they had been hoodwinked; in later years no doubt it was the Russians' turn to kick themselves. In view of the recent granting of statehood to Alaska and Hawaii, the section dealing with these two states and Puerto Rico is of particular interest.

About one-quarter of the land area of the U.S. is in Federal ownership. This consists largely of forests, arid grazing lands, and land held for water supply purposes; the productive agricultural lands are under private ownership. The ways in which these lands are used occupy the first part of the book. The essentially economic topics of finance and of rights, ownership and tenure follow in the next two sections.

The only real link with the 1957 Yearbook is the section devoted to technical aspects of land usage, such as soil testing, the development of irrigation, land classification, and so on. The management of forest lands receives individual attention. The final sections deal with the problems of land usage facing the U.S. today, and the means by which these problems may be overcome.

Over the years we have come to expect in each Yearbook an authoritative and thorough coverage of a particular agricultural topic which is at the same time attractively presented and fairly easy reading for the layman. This volume meets these criteria. A. W. MOORE

The Agricultural Regions of the United States. L. Haystead and G. C. Fite. Pp. xx+288, with line and half-tone illustrations, University of Oklahoma Press. First edition, 1955; second printing, 1956. Methuen & Co. Ltd., London. 42s. net.

Rather over 30 years ago the late Dr. O. E. Baker, at that time Agricultural Economist in the U.S. Department of Agriculture at Washington, published a series of papers on the Agricultural Regions of North America. The scheme of regions he drew up was destined to pass into textbooks of all types in many countries; it is still the basis of teaching the geography of North America in our own schools. Yet for some years past it has been clear that changes have been so profound in American agriculture as to render his regions and descriptions out of date. When, in 1926, he described the Corn Belt, that rich land focusing on the stockyards of Chicago, famed for its "cubical cattle and cylindrical hogs," the soybean had not even been introduced to the American farmer. Today United States acreage exceeds 15,000,000 and production 300,000,000 bushels. Haystead and Fite may be said to have produced the long overdue revision of Baker's regions, but their approach is different in many ways. The book is addressed to all who are "interested in why the greatest industrial nation in the world should also have the largest farm output and be one of the most varied in agricultural production." Although there is a folding map of great soil groups and the relative sections are reproduced for each region, less direct reference is made to soils and other physical factors in the text than to the overall influence of immediate economic factors: this is made clear both in the regions distinguished and the sub-titles given to them, and to the fact that each region is defined as a group of states, not according to agricultural boundaries.

After a warning regarding the non-existence of a "typical" American farm, eleven main regions are distinguished. New England is the Land of Abandonment, where land cleared at such labour by the Pilgrim Fathers and so much magnificent forest destroyed is now scrub woodland awaiting purchase by city dwellers as house-lots. The Middle Atlantic States (New York, New Jersey and Pennsylvania) have very varied soils and physical conditions: the great consuming centres in the midst provide the incentive to farming, hence the title "Prime Market." Delmarva: Intensive Region describes the small, truck farming unit of Delaware, Maryland and tidewater Virginia, and it contrasts with the Middle South: Reorganizing Belt, where an agricultural slum has been reclaimed by the TVA. Although the Deep South has the subtitle The Shifting Cotton Belt it is made to include the cotton-less Florida as well as the Mississippi Delta of Louisiana, which Baker separated as a Sub-Tropical Coast Belt of sugar, rice and fruits. Texas is included but is also treated as an integral part of the South-west: Far Distances and Dry Skies. The inclusion of whole states in the regions also breaks down in what is described as the American Granary of the Western Prairies and High Plains, also commonly called the Wheat Belt and stretching from the Canadian border in North Dakota to the Panhandle of Texas, and focusing primarily on America's Black-earth or Chernozem Belt. The Corn-Soy Belt ("Feedbag of Democracy") of five states coincides closely with Baker's Corn Belt, while America's Dairyland, a title claimed by Wisconsin, has been extended to include also Michigan and Minnesota. The Rocky Mountain States, sub-titled a Farm in the Sky, are five—"mountains are the dominant feature and tourists a rich cash crop." The unsatisfactory title of the Western Slope: Land of Tomorrow is given to the seven western states, in no sense a unit except that to the easterner this is the unknown land beyond the Rockies.

The book is written in a journalistic style, designed to extend its popular appeal, but many readers will only be irritated and perhaps led to wonder whether the authors can be regarded as serious and reliable. For example, on page 12 we read "corn is a grass. How it developed the cob, no one knows. It does not seem likely that it started existence that way." Or again, in a couple of pages introducing the Western Slope, we read "here geologic factors are strong. Physiographic factors cannot be denied. But economics, obviously, will have more to do with the future. . . . Although one of the writers has specialized in reporting its mutations for twenty-five years, still we face our self-assigned job with no little queasiness in our intellectual stomach." For most readers a more straightforward style would have aided digestion.

L. DUDLEY STAMP

ABSTRACTS

CROP PRODUCTION

Earthworms and soil fertility. 3. The influence of earthworms on the availability of nitrogen. K. P. Barley and A. C. Jennings, *Aust. J. agric. Res.*, 1959, **10**, 364–70.

Young worms of the species *Allobophora calignosa* (Sav.) were introduced into a medium containing fine ground plant litter and 0·20% N 190 hours after it had been wetted, and after a further 125 hours they were removed and their urine and faeces collected and analysed. Sample cores of the medium were taken at 0, 190, 290, 315 hours after wetting and sampled for ammonia, nitrate and other soluble N and total N. A graph illustrates the variation of nitrogen content of the medium with time. Of the non-available forms of nitrogen ingested 6·4% excreted by the worms was in forms available to plants. Measurements were also made of the rates of oxygen consumption and nitrate and ammonia production during the decomposition of herbage litter and dung in soil both with and without the presence of worms. In the presence of worms more oxygen was consumed, partly owing to the interaction between the worms and the other decomposers present, and the nitrate+ammonium N increased by 50 p.p.m. in 50 days. E.M.A.

The effect of farmyard manure on fertilizer responses. D. A. Boyd, *J. agric. Sci.*, 1959, **52**, 384–91.

The results of trials with N, P, K and dung on potatoes in Durham 1904–07, Yorkshire 1939, Rothamsted 1937–50, Cheshire 1949–52, and Yorks and Lancs 1950–54 have been re-examined. Even in the presence of dung there were interactions between each of the fertilizer nutrients. Dung increased the response to N applied alone but decreased the N response where basal P and K fertilizers were also applied. For P the results were similar to those for N. Since most of the sites were low in K, the responses to K were very large especially in the presence of basal N and P fertilizers; these responses were greatly reduced in the presence of dung, particularly when N and P fertilizers were also applied. The effective quantities of nutrients provided by 10 tons of dung are estimated to be 0·3 cwt N, 0·4 cwt P_2O_5 and 0·75 cwt K_2O. It is concluded that on average land the same compound fertilizer can be used whether or not dung is given, but the amount of compound can be reduced in the presence of dung (4 cwt of 12 : 12 : 18 or 5 cwt of 9 : 9 : 15 are equivalent to 12–15 tons of dung). S.F.A.

The growth of legumes in conjunction with phosphate fertilizer, as a means of increasing and stabilizing soil fertility and agricultural productivity, in Greece. D. A. Panos, *Emp. J. exp. Agric.*, 1959, **27**, 98–106.

Trials were carried out at Larissa Experimental Station in 1949–57 on rotations in which wheat alternated with various annual legumes. The legumes received 0 or 30 kg. N/ha. and 0, 30 or 60 kg. P_2O_5/ha.; the wheat received no fertilizer. Superphosphate at 30 kg. P_2O_5/ha. increased the dry grain yield of all legumes, the largest mean increase over the eight years being from 9·7 to 17·1 q./ha. with broad beans, and the smallest from 10·7 to 12·2 q./ha. with lentils. In 1955 analysis of legume seed showed increased phosphate and protein contents after superphosphate. Mean wheat yields after legumes that had received no fertilizer or N only were about 17 q./ha. dry grain; after legumes that had received superphosphate the mean yields ranged from 17·5 q./ha. after chick peas to 19·5 q./ha. after broad beans. Nitrogen fertilizer gave no improvement in yield or composition of the legumes nor in yield of the following wheat. S.F.A.

The value of calcium nitrate for spring-sown cereals. F. V. Widdowson, A. Penny, R. J. B. Williams and G. W. Cooke, *J. agric. Sci.*, 1959, **52**, 200–5.

Seven experiments on spring barley and five on spring wheat near Rothamsted in 1955–57 compared combine-drilled and broadcast dressings of ammonium sulphate and calcium nitrate at 0·3 and 0·6 cwt N/acre. With barley ammonium sulphate could be safely drilled and consistently gave higher yields than when broadcast; calcium nitrate could be drilled at 0·3 cwt N/acre but at 0·6 cwt N/acre it retarded germination and early growth in dry springs, especially on light soils and on badly prepared seedbeds. With wheat both fertilizers gave higher yields when broadcast than when drilled although ammonium sulphate did not noticeably check germination when drilled. Calcium nitrate and ammonium sulphate gave similar yields and nitrogen contents of both crops when broadcast. In each year the increase in barley yield from 0·6 cwt N/acre was highly profitable; the response of wheat to nitrogen was smaller. No appreciable lodging occurred at any centre. S.F.A.

Nitrogen content of barley grain. An examination of the percentage of nitrogen in barleys grown in the Eastern Region and the effect of late top dressing with 'Nitro-Chalk.' E. R. Bullen, *Exp. Husbandry*, 1959, (4), 28–33.

During 1953–55 non-replicated trials were carried out at 132 sites. In the absence of late top dressing the nitrogen content of the grain gave ranges and means of 1·25–2·09 and 1·56% N for "Archer" type, 1·15–2·14 and 1·51% N for Carlsberg and Proctor, and 1·36–2·27 and 1·67% N for Scandinavian barleys. Nitrogen content tended to be increased in all types by late sowing. In 1953 and 1954 Scandinavian barleys gave higher grain N on heavy land than on light or medium whereas soil type had no effect on "Archer" type barleys; in 1955, which was a dry season, soil type had no effect on Scandinavian barleys whereas "Archer" type barleys had higher grain N on light or medium than on heavy land. 'Nitro-Chalk' was applied at 2 cwt/acre at the flowering stage; mean responses were: "Archer" type 0·34, Carlsberg and Proctor 0·22, Scandinavian barleys 0·18. The response in 1955 was much less than in 1953 or 1954. Yields were not measured. S.F.A.

The response of *Hevea brasiliensis* to fertilizers in Ceylon. D. H. Constable and G. E. Hodnett, *Emp. J. exp. Agric.*, 1959, **27**, 150–7.

Trials since 1940 to investigate the effect of fertilizers on the girth of trees prior to tapping are summarised. There was in general a response to phosphate and to nitrogen; the effect of potassium was more variable and may have been influenced by the magnesium status of the trees. Girth in 1944, immediately prior to tapping, was significantly related to the total yield of latex in 1944–47 but the relation between girth in 1944 and latex yield in 1948–50 was not significant. S.F.A.

Pasture soil compaction by animal traffic. C. B. Tanner and C. P. Maramil, *Agron. J.*, 1959, **51**, 329–31.

Compaction measurements which included those for air permeability, soil penetrability, aeration porosity and bulk density were made on several pastures on different soil types and compared with those on either adjacent hay fields or adjacent fence lines where animals grazed but could not tread. On all the pastures under trial except one, a coarse silt loam containing little clay, the compaction measurements were greatly decreased by grazing indicating that pasture soils suffer severe damage through animal traffic. The yields of a lucerne-brome grass-ladino clover pasture in its first grazing year were decreased 20% by animal compaction. It is emphasized that pasture management which permits grazing during or shortly following rains, when the soils are plastic, may affect yields detrimentally owing to increased compaction of the wet soil. E.M.A.

A study of growth in swards of timothy and meadow fescue. II. The effects of cutting treatments. R. H. M. Langer, *J. agric. Sci.*, 1959, **52**, 273–81.

Pure swards of S48 timothy and S215 meadow fescue were cut (*a*) after ear emergence, (*b*) before ear emergence and in the aftermath to prevent flowering, and (*c*) every 4 weeks. The number and weight of tillers and leaves were determined. Tiller numbers declined considerably from early spring to the middle of summer. This fall was reduced by a system of frequent defoliation in the wet summer of 1956, especially in timothy. Leaf weight per unit area of sward increased rapidly from early spring until about the time of ear emergence; no further significant gains were recorded after ears had appeared, when the plots were cut for hay. The weight per leaf also increased in the spring and was similar in both species. In the regrowth following a cut meadow fescue produced considerably heavier leaves than timothy. As both grasses approached the flowering stage, their leaf canopy was increasingly raised above ground level. Variable proportions of foliage were thus removed by cutting according to the developmental stage of the plant. Crop growth rates following a cut appeared to be related to the amount of leaf material remaining in the sward. Relative growth rates during uninterrupted growth were greatest around the time of ear emergence. (*Author's summary.*)

Competition for nutrients between grasses and white clover. I. Effect of grass species and nitrogen supply. M. C. H. Mouat and T. W. Walker, *Plant and Soil*, 1959, **11**, 30–40.

When phosphate was the limiting factor, dry matter yield of clover was 6–11 g./pot when grown alone, 3–5 g./pot when grown with cocksfoot or browntop, and 1–2 g./pot with short-rotation ryegrass. When potash was the limiting factor the corresponding yields were 6–8 g./pot when grown alone, 2–4 g./pot with cocksfoot or browntop, and 1–2 g./pot with ryegrass. In the grass/clover associations there was in all cases a highly significant reduction in clover yield when nitrogen was applied; clover yield was inversely related to the yield of the associated grass. When herbage was cut three times in order to reduce the effect of competition for light there were large responses of clover to phosphate and potash. When herbage was left uncut until the final harvest phosphate application increased clover production in browntop associations and to a lesser extent in cocksfoot associations but had no effect on clover in ryegrass associations; no corresponding experiment was carried out with potash. S.F.A.

Growth and nutrition of timothy (*Phleum pratense* L.). IV. The effect of nitrogen, phosphorus and potassium supply on growth during the first year. R. H. M. Langer, *Ann. appl. Biol.*, 1959, **47**, 211–21.

In a sand-culture experiment lasting 21 weeks plants of timothy grown from seed were maintained at all combinations of three levels of nitrogen, phosphorus and potassium. The number and weight of tillers, leaves and ears, and the weight of roots, were determined at the end of the experiment, and for some of the treatments at intervals of 4 weeks. All three nutrients had significant effects, especially N which at its lowest level of supply tended to mask the effect of the other two elements. Potassium influenced tiller numbers least, especially those of primary tillers, but in the presence of high concentrations of N and P it had a large effect on leaf area and dry weight. Relative growth and net assimilation rates responded to varying nutrient supply only in the early stages of growth, so that in general variations in dry weight were associated with nutrient effects on leaf area. (*Author's summary.*)

CROP PROTECTION

Accumulation of DDT in the soil of an Ontario peach orchard. D. C. Herne and D. Chisholm, *Canad. J. Soil Sci.*, 1958, **38**, 23–26.

The distribution of DDT in the soil was investigated in a peach orchard in Ontario in which the insecticide had been applied in known quantities from 1946 to 1954. In the first two years sprays had been applied with considerable run-off; run-off was slight in 1949–51, and in 1952–54 the use of a mist blower had resulted in run-off being negligible. Even so, run-off was the main factor responsible for the build-up of DDT in the soil. About 95% of the accumulated DDT was held in the top soil, which was cultivated, and the concentration present close to the trunks of the peaches was significantly higher than that halfway between adjacent trees. D.L.

Dieldrin versus diazinon in the control of the olive fruit fly (*Dacus oleae* Gmel.) in Israel. Z. Avidov, I. Moore and I. Harpaz, *Ktavim*, 1958, **8**, 117–26.

In field trials conducted in 1955 on the coastal plain of Israel to compare the efficiency of dieldrin and diazinon against *Dacus oleae* on early and late varieties of olive, dieldrin gave the best results as a preventive spray. On early-maturing varieties, there was no significant difference between the net percentage survivals from the use of 0·06% diazinon or 0·2% dieldrin with 0·03% diazinon and that from untreated trees, nor between one application of 0·2% dieldrin wettable powder or emulsion and two applications of 0·2% dieldrin wettable powder made a month apart, but dieldrin reduced the infestation rate to between 9·4 and 14·6% from 22·7% on the untreated trees. The combination of diazinon and dieldrin failed to control honey-dew-producing insects, and the toxicity of the dieldrin was reduced. The use of 0·2% dieldrin wettable powder resulted in residues in the harvested fruits of 0·1 p.p.m. or less, but 0·3 p.p.m. was determined in fruits that had been sprayed with 0·2% emulsion. Diazinon residues were 0·1 p.p.m. from the use of 0·06% emulsion and 0·01 p.p.m. from 0·03% wettable powder with dieldrin. On late olives, diazinon emulsion sprays at 0·04, 0·06, 0·08 and 0·1% active ingredient reduced the infestation to 7·3, 7·0, 1·6 and 1·3, respectively, as compared with 9·5% infestation on untreated trees. The infestation occurred too early in the season for the preventive use of dieldrin to be assessed. D.L.

Seed dressings for control of maggots and diseases attacking certain field and vegetable crops in southern Ontario, 1956. L. A. Miller and R. J. McClanahan, *Proc. 10th int. Congr. Ent.*, 1958, **3**, 301–6.

Hylemyia cilicrura is the most important soil pest of legumes, maize and cucurbits in southern Ontario. Control was obtained by coating seeds with a mixture of 0·4 oz. heptachlor, dieldrin or aldrin and 1·5 oz. thiram or captan per

100 lb. seed, for it was found that the use of insecticides alone was not always effective. Dressing onion seed with 1 oz. heptachlor or dieldrin and 2 oz. thiram per 1 lb. seed effectively controlled both the onion fly (*H. antiqua*) and smut caused by *Urocystis cepulae*. It is suggested that, in view of the increased stands obtained as a result of using such double-purpose seed treatments, the sowing rates for many crops should be revised. D.L.

Effects of previous wheat crops, seed-rate and nitrogen on eyespot, take-all, weeds and yields of two varieties of winter wheat: Field experiment 1954–56. M. D. Glynn and D. B. Slope, *Ann. appl. Biol.*, 1959, **47**, 187–99.

A field at Rothamsted which had carried oats in 1952 and potatoes in 1953 was in 1954–56 divided into four cropping sequences: (*a*) wheat each year, (*b*) potatoes, wheat, wheat, (*c*) wheat, potatoes, wheat, (*d*) beans, potatoes, wheat. The beans and potatoes were treated as normal non-experimental farm crops. Holdfast and Cappelle winter wheats were sown at 1½ and 3 bu./acre (2 and 4 bu./acre for Cappelle in 1955 and 1956) and received 'Nitro-Chalk' top dressings of 3 and 6 cwt./acre (52 and 104 lb. N/acre) half in March and half in May. Previous wheat crops had more effect than any other treatment in increasing the incidence of eyespot, take-all and weeds and in decreasing the number of ears per unit area and the yield of grain. Eyespot was more severe on Holdfast than on Cappelle, and take-all tended to be more severe on Cappelle than on Holdfast. Cappelle consistently yielded more than Holdfast, the mean difference being 13·8 cwt./acre after potatoes but only 3·8 cwt./acre after two wheat crops. After potatoes the higher seed rate increased the grain yield by about 4½ cwt./acre, but in the most severely diseased crops the higher seed rate reduced grain yield by nearly 1 cwt./acre. The increased grain yield from the higher rate of 'Nitro-Chalk' averaged 3 cwt./acre for Holdfast and 5 cwt./acre for Cappelle. S.F.A.

Effect of nitrogenous fertilizer applied at different dates on take-all, eyespot and yield of winter wheat grown on light sandy loam. G. A. Salt, *Ann. appl. Biol.*, 1959, 47, 200–10.

A field at Woburn which had been cropped with potatoes in 1953 carried three successive crops of Holdfast and Cappelle winter wheats in 1954–56. Nitrogen was applied each year in March, April, May, or half in March and half in May. Grain yields from 0, 3 and 6 cwt./acre of 'Nitro-Chalk' averaged 20, 26 and 33 cwt./acre in 1954, 9, 14 and 19 cwt/acre in 1955, and 5, 10 and 13 cwt/acre in 1956. The percentage of straws infected by take-all in July averaged 9% in 1954, 15% in 1955, and 26% in 1956; eyespot was present each year but did not become prevalent. 'Nitro-Chalk' applied in April yielded most grain every year, and wheat fertilized then had less eyespot and take-all than that fertilized in March. Nitrogen applied in May increased weed growth, failed to decrease take-all, and yielded fewer ears, less grain, and a higher proportion of tailcorn than did earlier applications. S.F.A.

Colletotrichum coffeanum Noack. P. Henrard, *Agricultura, Louvain*, 1957, **5**, 39–55.

One of the most serious diseases of *arabica* coffee in the Belgian Congo is caused by *Colletotrichum coffeanum*. In 1954–56 many fungicides were tested against the brown blight form of the disease, and materials showing encouraging activity on a local resistant coffee variety were then tested on the susceptible variety Mbirizi. The fungicides were applied at 1 litre/tree at 14-day intervals. Captan at 0·25% gave good control, but for severe infections it was better at 0·5%; Fermate at 0·25% was not so good on Mbirizi as it had been on the resistant variety; Tuzet at 0·125% gave excellent control, but after four applications the trees showed symptoms of arsenical poisoning. Most materials, including Phygon, Perenox, Cupravit, Tersan, zineb and fuclasin, were unsatisfactory. D.L.

Onderzoekingen over de biologische overdracht van een non-persistent virus. (Investigations on the biological transmission of a non-persistent virus.) H. A. Van Hoof, *Meded. Inst. PlZiekt. Onderz.*, 1958, **161**, 96 pp.

In studies on the mechanism of virus transmission by aphids, it was found that *Myzus persicae* readily acquired lupin mosaic virus from entire broad bean leaves, but could only do so from the stripped epidermis when the stylets penetrated a cell. There was poor transmission from spongy parenchyma (after the epidermis had been stripped), when the stylets took an intercellular course. It was concluded that the virus is acquired from within the cell wall. The aphids were unable to transmit virus from leaves that had been killed by heat, freezing or by chemical agents, although mechanical transmission was still possible from the leaves killed by physical methods. Transmission was reduced by lowering the water content of leaves, and the process was reversible. *M. persicae* and *Aphis fabae* were able to transmit virus from infected plasmolysed leaves, and to infect healthy plasmolysed leaves, but the latter could not be inoculated by mechanical means. D.L.

The control of cotton root-knot by the addition of 1,2-dibromo-3-chloropropane to irrigation water. D. J. Morton, *Plant Dis. Reptr*, 1959, **43**, 243–47.

In field trials in New Mexico, a high degree of control of root-knot nematodes (*Meloidogyne* sp.) on cotton was achieved by the use of 1,2-dibromo-3-chloropropane in the normal irrigation water 10 days before planting of the crop. Actual toxicant in emulsifiable form was used at 1 gal./acre, applied at the flood-gate between ditch and field from a drum containing the amount calculated for the irrigated area and diluted to give a volume of 25 gal. Seedling stands were slightly decreased by the treatment; averages were 760 seedlings/100 ft. row in treated fields and 834 in untreated fields. Less than 1% of the roots were found to be galled at harvest, as compared with about 35% in untreated fields, and the yields averaged 1·3 and 0·6 bales/acre, respectively. D.L.

The decomposition of herbicides in soils. P. Burschel and V. H. Freed, *Weeds*, 1959, **7**, 157–61.

The breakdown of some herbicides, in a loamy soil at 15 and 29° C and with a moisture content of 50% of its field capacity, was found to occur as a first order reaction. The percentage of original concentration (20 p.p.m.) of amitrol and CIPC remaining after six weeks at 15° C was 48 and 75, respectively, and, at 29° C, 30 and 0. IPC was decomposed much more rapidly; of an original concentration of 2 p.p.m., 26·5% remained after 16 days at 15° C and none at 29° C. These experimental findings are similar to results from field observations. The actual rate of breakdown found at the highest concentration at 29° C was 1·31 μg./g. soil/day for amitrol, 0·25 μg. for IPC, and 0·085 μg. for CIPC. The soil life of herbicides may therefore be computed, assuming that there is adequate soil moisture for microbiological activity and that allowance is made for autodecomposition and leaching. D.L.

Experiments on the control of broomrape in red clover. W. E. Davies, *Plant Path.*, 1959, **8**, 19–22.

Several fields of the Welsh Plant Breeding Station are heavily infested with broomrape (*Orobanche minor*). In 1952–54, a pilot experiment was carried out with sowings of broomrape in boxes. Cropping with linseed reduced the number of broomrape plants in the boxes and almost doubled the fresh weight of red clover produced by a subsequent sowing. The response was not so marked in the field, for in a trial established in 1953 there was no significant fall in the numbers of broomrape plants even after two linseed crops had been grown. Dusting the red clover seed with such mercurial dressings as Soprasan or Agrosan G had no effect on the broomrape. In Algerian trials with seed dressings against broomrape on peas, encouraging results had been achieved, and the poor results on clover are thought to be due to the fact that clover occupies the ground for a longer period than peas, and that in the latter crop a temporary inhibition of broomrape might be sufficient to prevent the parasite from becoming established. D.L.

ANIMAL HUSBANDRY

Haymaking—experiments on tedding at Trawscoed. J. Y. Holmes, *Exp. Husbandry*, 1959, (4) 41–50.

Cocksfoot/clover hay was tedded for the first time immediately, 24 hours or 48 hours after cutting. Hay from each treatment was baled at 30%, 25% and 20% moisture content. Immediate tedding gave quicker and more even drying than tedding 24 hours later in two years out of three, and the hay tedded immediately was ready for baling 1–2 days before that first tedded after 48 hours. Even when rain fell after tedding no difference in loss of nutrients was observed between the broken and unbroken swaths. The feeding value of the hay was assessed after six months. There were no consistent differences associated with the tedding systems, and the differences between hay baled at 20% and 25% moisture were slight, but sugar content, colour and smell were markedly inferior when hay was baled at 30% moisture. Protein percentage varied from year to year but was not much affected by any treatment in any one year. S.F.A.

The effect on milk composition of feeding spring grass to cows. R. Waite, M. E. Castle and J. N. Watson, *J. Dairy Res.*, 1959, **26**, 173–81.

Two similar groups of lactating Ayrshire cows were used in this trial. Group 1, consisting of six animals, was fed a good quality winter ration throughout the twelve-week experimental period, while Group 2, with seven animals, was fed indoors on cut spring grass during a six-week period interposed between two three-week periods on winter rations. This grass which was cut at 6.30 a.m., 11.30 a.m. and 4 p.m. was fed in four equal lots at 7 a.m., noon, 4.30 p.m. and 7 p.m. Changes from the winter feeding to grass was made over a period of one week after which time 160–180 lb. grass was offered to each cow daily. Concentrates were also fed in addition when it was estimated that the intake from the grass alone supplied insufficient nutrients for high yielding cows. Tables show analysis and approximate feeding values of the winter rations and spring grass and details of the pre-calving diets are also given. The mean yield and percentage composition of the milk is averaged over three-weekly sub-periods. Percentage fat content of the milks are given as follows: Group 1, 3·53, 3·72, 3·72, 3·82; Group 2, 3·57, 3·75, 3·70, 3·81. The % values found for the s-n-f were: Group 1, 8·72, 8·76, 8·78, 8·81; Group 2, 8·68, 8·83, 8·87, 8·88, while the % values for crude protein were determined as: Group 1, 3·18, 3·27, 3·28, 3·38; Group 2, 3·07, 3·22, 3·24, 3·25. The milk yield and composition changes were mainly those associated with advancing stages of lactation and feeding of cut spring grass had little specific effect. It is suggested that the increase in milk protein content which is often observed soon after the start of spring grazing probably results from the improved plane of nutrition. E.M.A.

The growth and appetite of sheep on high-fibre low-protein diets supplemented with urea and molasses. N. M. Williams, G. R. Pearce, M. Delaney and D. E. Tribe, *Emp. J. exp. Agric.*, 1959, **27**, 107–16.

The loss of weight between 9th August and 7th October 1956 in Australia of 48 wethers aged 2½ years, fed on poor-quality oat straw, averaged 19 lb./sheep whereas 48 similar sheep receiving a supplement of 10 g. urea + 38 g. molasses per 1 lb. straw lost only 12 lb./sheep. The whole of the reduced loss of weight was due to increased feed consumption. A digestibility trial with 6 of these sheep showed that urea/molasses did not improve the digestibility of the dry matter, crude fibre, or ether extract, but markedly improved the apparent digestibility of the crude protein. A further trial with 88 of the same sheep showed that between 22nd October and 19th December sheep receiving protein-rich grass/clover hay gained 19 lb./sheep whereas those receiving oat straw and 10 g. urea + 38 g. molasses/sheep/day lost 3 lb./sheep. No improvement was effected by giving urea/molasses to the sheep fed with grass/clover hay, by supplementing the oat straw/urea/molasses with sodium sulphate, vitamin B complex, ethyl alcohol, or all of these, or by replacing the urea with sodium nitrate. S.F.A.

Oestrogens in British pasture plants. G. S. Pope and M. J. McNaughton. *J. Dairy Res.*, 1959, **26**, 196–202.

Many grass and legume plants commonly found in British pastures were sampled at various growth stages and tested for oestrogenic activity by the mouse uterine weight technique. Extracts from all the *Medicago* species sampled including five varieties of *M. sativa* (lucerne), *M. lupulina* (black medick), *M. falcata* (sickle lucerne) and *M. media* (sand lucerne) showed activity. Of the six *Trifolium* species under test only four were active. These were: *T. repens* (white clover strain S100, Kent wild white and New Zealand strains), *T. pratense* (red clover strain S151), *T. hybridium* (alsike clover) and *T. incarnatum* (crimson clover). The inactive species were: *T. fragiferum* (strawberry clover) and *T. dubium* (suckling clover). The quantity of oestrogen present varied with maturity stage and in *T. repens* it appeared to be at a maximum around flowering time, at the end of June. Only six of the fourteen grass species sampled showed activity; these were: *Agrostis tenuis* (common bent), *Dactylis glomerata* (cocksfoot), *Festuca elatoir pratensis* (meadow fescue strain S215), *Festuca rubra* (red fescue var. *arenaria*), *Lolium italicum* × *L. perenne* (short rotation ryegrass) and *Poa trivalis* (rough stalked meadow grass). The inactive species of grasses included *Agropyron repens* (couch grass), *Alopecurus pratensis* (meadow foxtail), *Bromus inermis* (awnless brome grass), *Cynosurus cristatus* (crested dog's tail), *Holcus lanatus* (Yorkshire fog), *Lolium italicum* (Italian ryegrass var. giant evergreen), *L. perenne* (perennial ryegrass var. Ayrshire) and *Phleum pratense* (timothy). It is stated that these experimental results also suggest that the oestrogen present in British pasture plants is insufficient to affect milk composition but further experiments are needed to elucidate this point. E.M.A.

Sarcosine and creatine as nitrogen sources for the ruminant, and the influence of supplemental vitamin B_{12}. C. D. Campbell and others, *J. Anim. Sci.*, 1959, **18**, 780–9.

Four trials with wether lambs averaging 30 kg. body weight were conducted, the animals being fed semi-purified diets containing 4·5 p.p.m. cobalt chloride and 1·7% nitrogen of which two-thirds was supplied either by urea or creatine alone or combinations of urea and creatine or sarcosine. Tables show full details of the rations fed, nutrient digestibility and nitrogen metabolism. Nitrogen from rations containing creatine and sarcosine was utilized as effectively as that in urea rations. Vitamin B_{12} improved the digestibility of organic matter, crude protein and crude fibre markedly and when fed with creatine also increased the retention of absorbed nitrogen especially during the early stages of the trial. E.M.A.

Bloat in cattle. 13. The effect of orally administered penicillin on the fermentation and foaming properties of rumen contents. J. L. Mangan, A. T. Johns and R. W. Bailey, *N.Z. J. agric. Res.*, 1959, **2**,342–54.

The experiment was carried out with a pair of identical twin cows, which in a preliminary trial had shown similar bloating patterns. Penicillin in the form of lactose-based procaine penicillin tablets of 100,000 units was administered orally at irregular intervals to one of the cows in doses ranging from 100,000 to 500,000 units. Investigations were made on the foaming properties of both crude and clear rumen liquor samples and *p*H, bloat grade and nitrogen contents were determined. The foam expansions and the foam stabilities of the crude rumen liquor from the penicillin-treated cow were very low compared with those for the control animal, volatile fatty acid and ammonia production and also protein breakdown were inhibited by the treatment. It appears that penicillin owes its effectiveness to its action in depressing gas production and to its effect on the foaming properties of the rumen contents. Resistance to the effect of penicillin was soon found to develop, but animals left untreated for a period soon recovered sensitivity to its action. E.M.A.

Penicillin and other antibiotics in milk. Anon, *J. Amer. Med. Ass.*, 1959, **171**, 49.

In the U.S.A. widespread use by dairy farmers of penicillin for the treatment of mastitis by injection through the teat canal has led to the contamination of bulk milk supplies with penicillin because the farmers have neglected to wait for 3 days before selling the milk of so-treated cows. The controlling authorities have permitted penicillin, etc., to be supplied direct to farmers although this has been contested by the veterinary profession. The situation has become worse during the last few years as the result of antibiotic manufacturers increasing the antibiotic content of their mastitis-remedy dosage formulations, backed by the argument that the bigger the dose the better the results. This is in fact not the case and, because of the evidence or belief that the presence of penicillin in milk causes sensitivity reactions in persons drinking it, the authorities have now given instructions that the unit dose of penicillin for mastitis therapy must not exceed 100,000 units and they are repeating with emphasis their instructions to farmers to withhold the milk of treated cows from the dairy bulk supplies for a full 3 days after the use of the last tube of antibiotic. If many cases of sensitivity to pencillin occur in persons drinking contaminated milk it will become necessary to tighten up the regulation still further. J.T.E.

Ist Penicillin in der Fütterung ein Probioticum oder ein Antibioticum? (Is penicillin in the ration a growth-promoter or an antibiotic?) K. Kaemmerer, *Vet.-Med. Nachricht.*, 1958, No. 4, 231–44.

The question that forms the title of this paper is about the mode of action of penicillin as a growth-promoter. It consists largely of a review with quotations from the literature and an account of some original experiments. There is now plenty of evidence that penicillin which has lost its antibacterial activity through inactivation by the action of penicillinase, chemicals or simply by prolonged storage, still possesses growth-promoting activity. The author shows the results of experiments on rats and chickens which indicated a 10% improvement in weight gain in rats when their ration contained 2–3% of inactivated *Penicillium* mycelium, while in the experiments with chickens penicilloic acid obtained as a break-down product of penicillin V had a significant growth-promoting activity as shown in controlled experiments. This author concludes that penicillin favours growth in young animals by a mechanism unconnected with its antibacterial activity. He therefore uses the word "probiotic" to describe this kind of action of penicillin. J.T.E.

Ringworm in cattle. I. M. Lauder and J. G. O'Sullivan, *Vet. Rec.*, 1958, **70**, 949–51.

Ringworm is a fungous infection of the skin and hair which has hitherto resisted control and the most effective type of treatment has consisted of X-ray irradiation, a difficult and hazardous procedure. In addition a few chemical antifungal preparations have had some success. Now a major discovery has been made whereby an antibiotic administered through the mouth has proved to be capable of eliminating ringworm fungi. This substance is griseofulvin. The backs of 7 calves were shaved and the skin was infected artificially either from material from naturally occurring ringworm or with a laboratory culture of the organism *Trichophyton verrucosum*. Four of the calves were then dosed daily with 60 mg./kg. body weight of griseofulvin. Ringworm did not get a hold upon them. The other 3 calves received no griseofulvin and developed ringworm lesions. After 3 months 2 of the untreated calves were treated with griseofulvin at the same dosage as above and after 1 week it could be seen that the ringworm had been arrested. During the subsequent weeks the ringworm lesions diminished progressively and disappeared before 12 weeks had elapsed. J.T.E.

Intramuscular carbon tetrachloride in the treatment of acute fascioliasis in sheep. J. A. Parry, *Vet. Rec.*, 1959, **71**, 536–7.

For over 30 years carbon tetrachloride given by the mouth in capsule has been the standard remedy for liver fluke disease in sheep. Under certain obscure conditions it is rather poisonous and is generally regarded as dangerous when sheep are badly damaged in the liver by a sudden massive invasion of flukes. When confronted with such an outbreak the author decided to inject carbon tetrachloride instead of giving it orally, and he mixed it in equal parts with liquid paraffin and gave it by intramuscular injection into the hind leg. The injection made the sheep lame for half an hour or so and a rapid pulse rate could be observed. This method of treatment seemed to be very effective in terminating outbreaks in several flocks and the beneficial effects were in evidence particularly between the 5th and 12th days after injection. The best dose appeared to be 4 ml. of the equal part mixture. 7400 sheep received this treatment during one autumn-winter period. J.T.E.

Printed in Great Britain at THE KYNOCH PRESS, *Birmingham*